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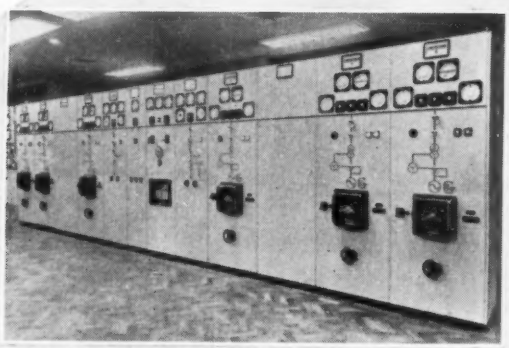
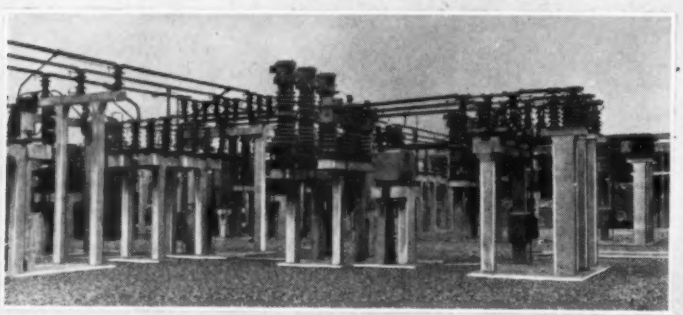
ROLLS-ROYCE LTD. DERBY. AERO ENGINE ALTITUDE TEST PLANT

WITH SWITCHGEAR SUPPLIED BY REYROLLE

The 33-kV 1000-MVA small-oil-volume switchgear and ancillary equipment controlling the supply to the six 22,000-H.P. compressor-motors was manufactured and installed by Reyrolle



Photographs by courtesy of Rolls Royce Ltd.
Consulting Engineers: McLellan and Partners in association with Messrs. Merz and McLellan



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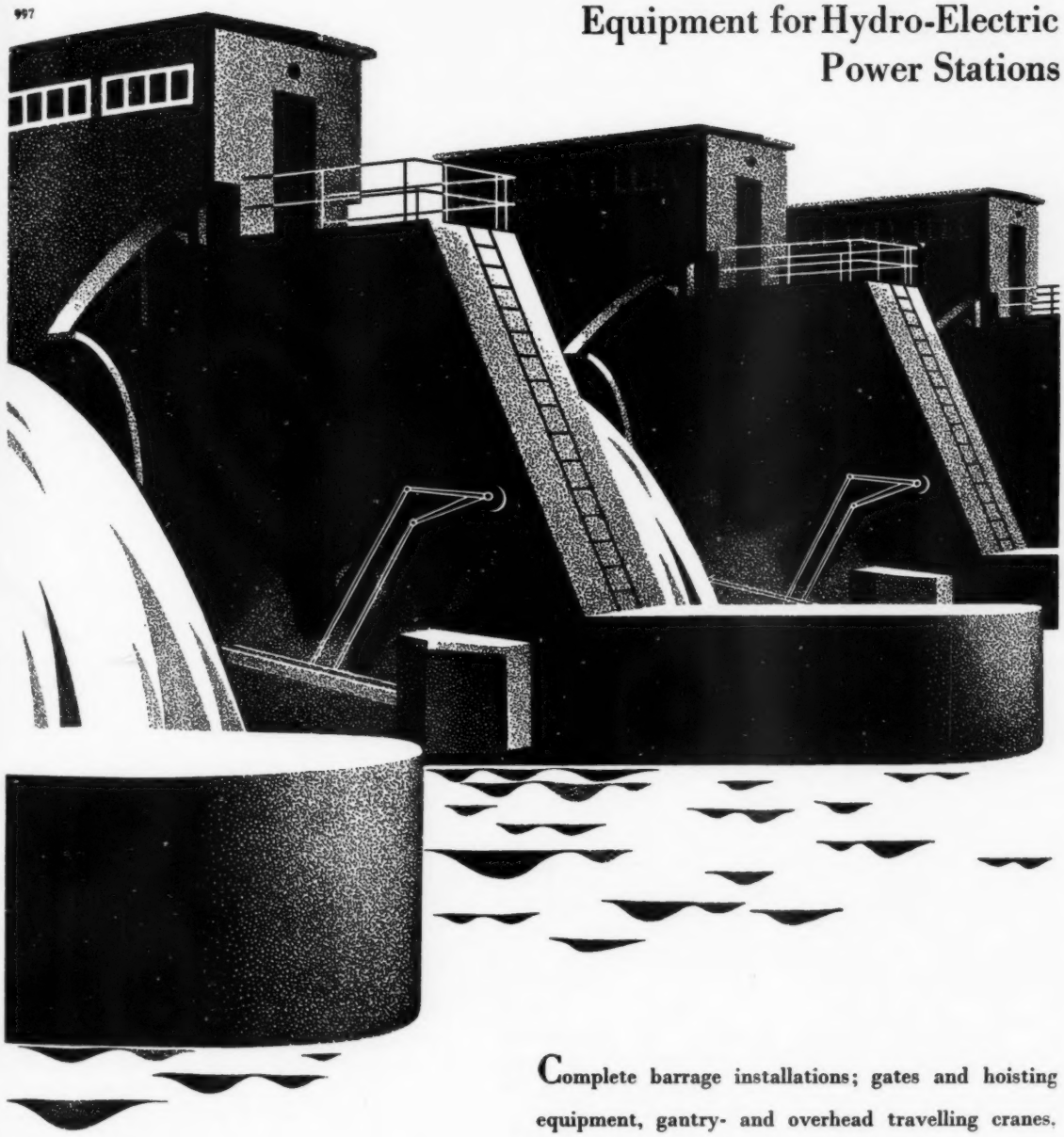
Equipment for Hydro-Electric Power Stations



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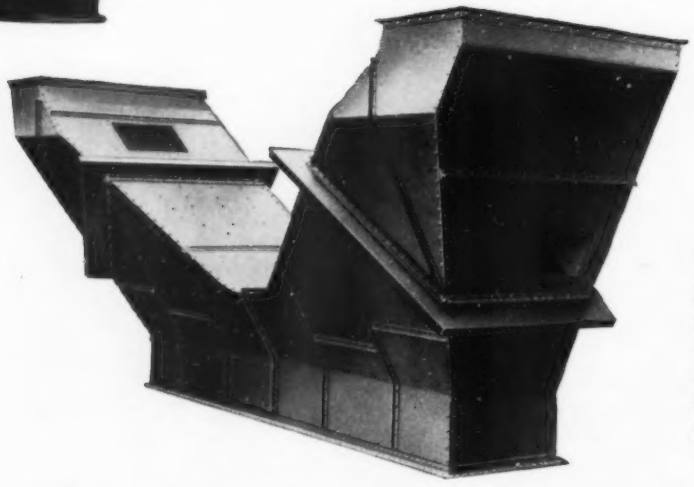

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Ducts of rectangular design for power stations or boiler houses, of electrically-welded construction in Mild or Special Steels or Aluminium Alloy, can also be supplied. They are accurately fabricated to suit your exact requirements.

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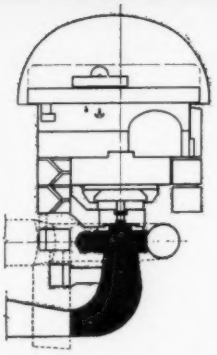
KARIBA—ON SITE—ON SCHEDULE

The Stay Ring for No. 1 Turbine at Kariba—shipped from England in May, 1958—is now in position. It is shown here installed in the vast underground power station, ready for the next major step, fabrication of the spiral casing.

This is the first of six Boving Turbines being installed at Kariba. Each is of 140,000 b.h.p.



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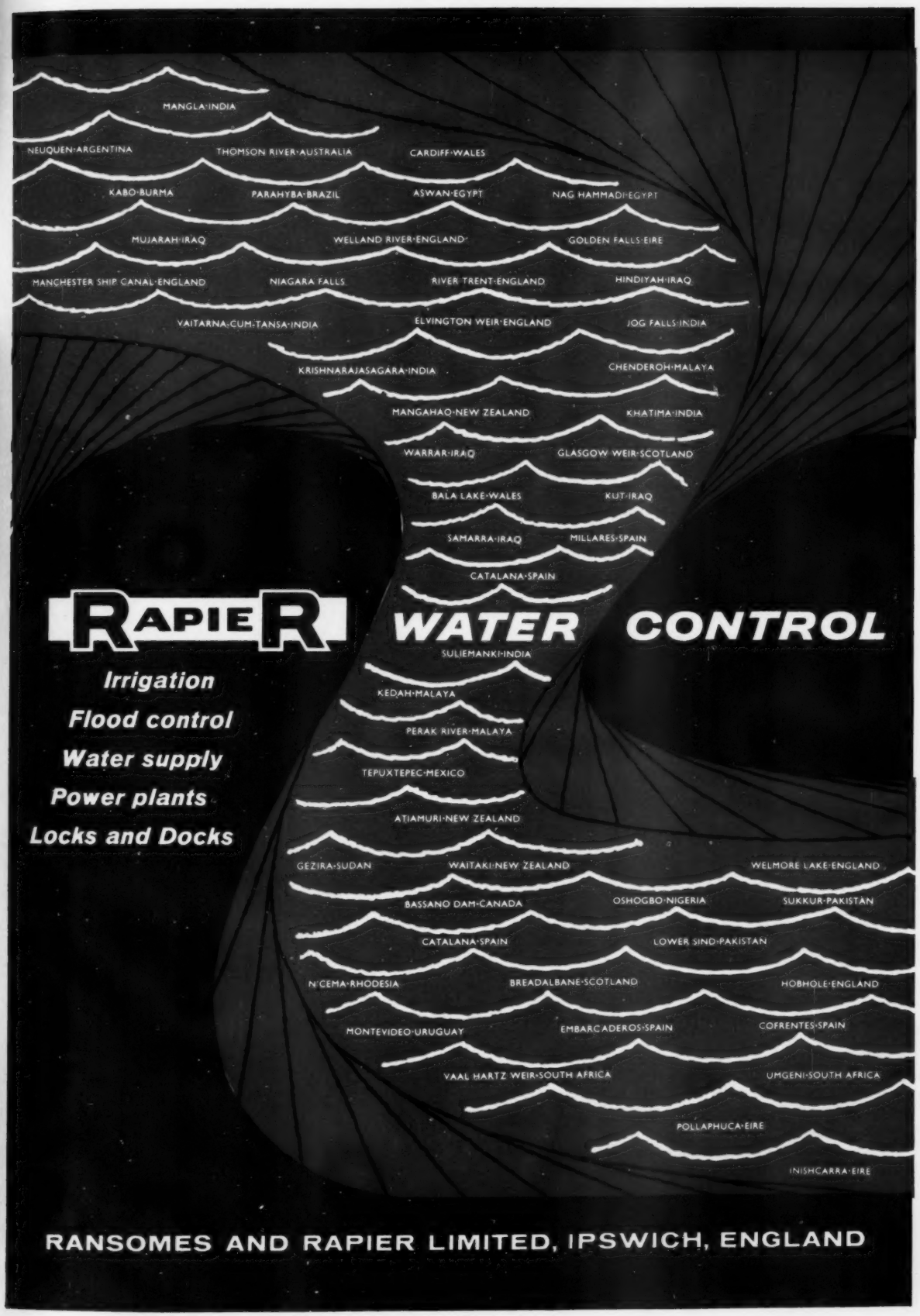
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ROCK DRILLS GO INTO ACTION

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THE JAL47 AIRLEG DRILL

for maximum footage in mining and tunnelling. One-hand feed control, perfect balance, high penetration speeds with low maintenance costs . . . the Air Leg Rock Drill removes strain from the operator — reduces drilling time, a controlling factor in maintaining good cycle times.

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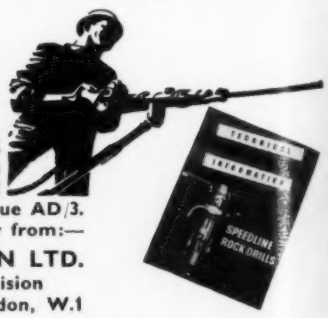

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All types of

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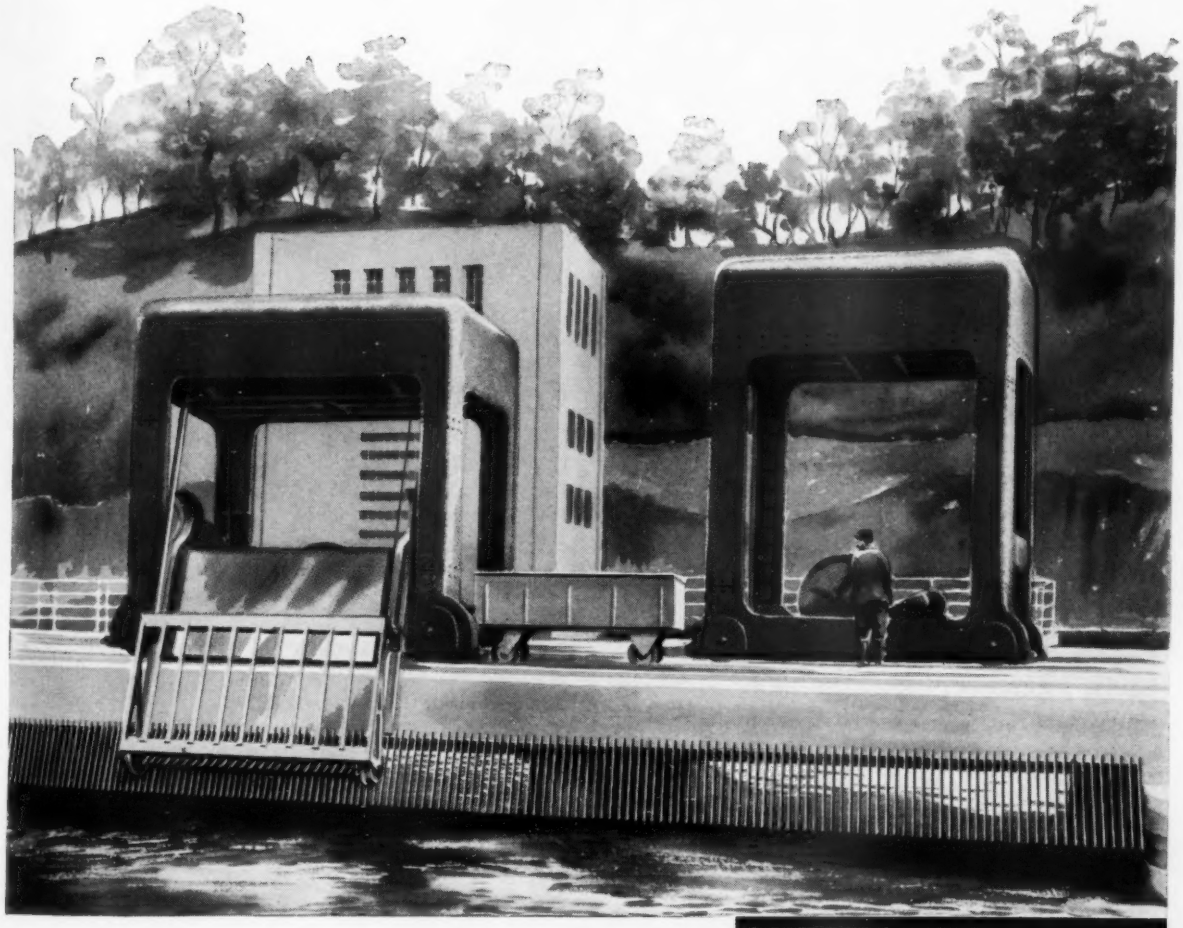
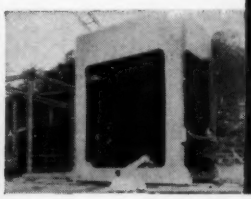


. . . screens, trash rakes and cranes for hydro-electric intake works . . .



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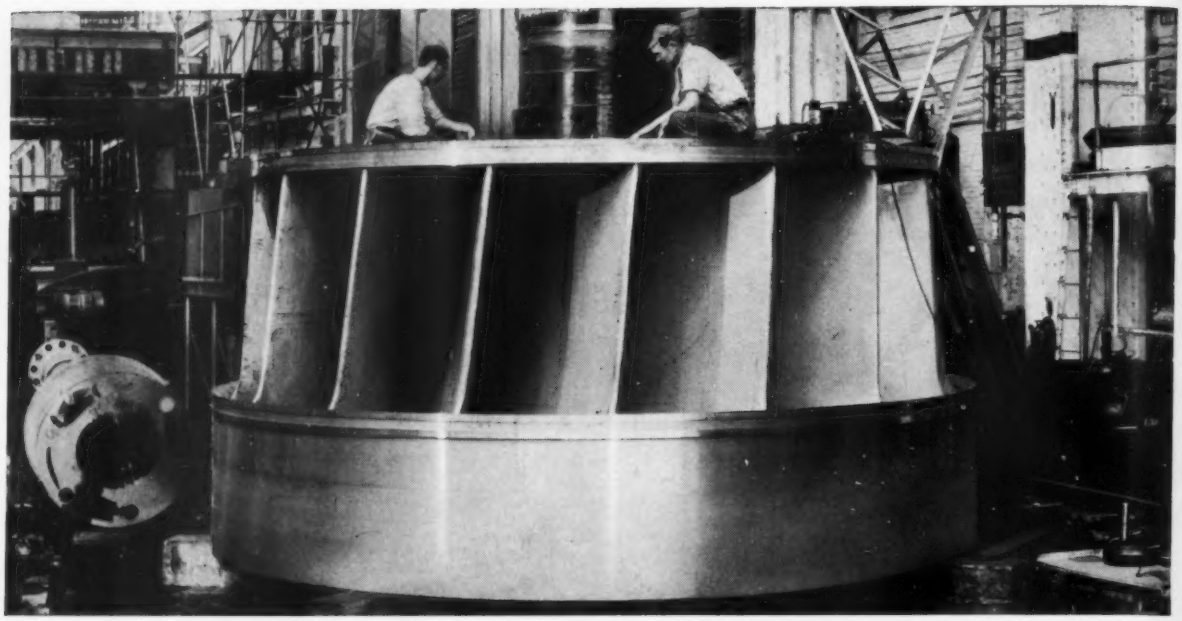
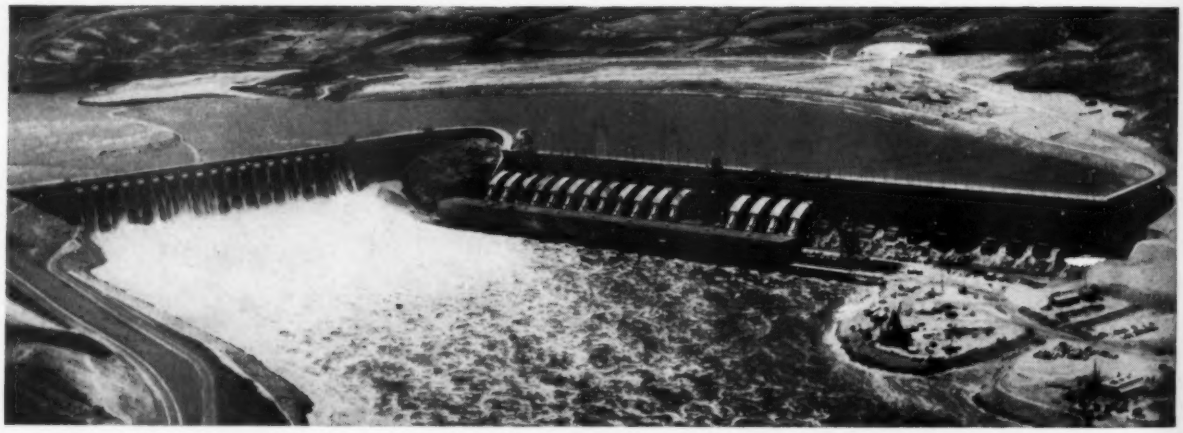


Newport News builds 10 unique runners



For Chief Joseph Dam in Washington State

Cast buckets are welded to cast crown and band—then stress relieved

The Francis-type runner above illustrates Newport News' complete facilities for fabricating heavy equipment.

It also illustrates the specialized techniques Newport News frequently uses in jobs of this type. Gibson tests for these units are very favorable.

Before you go ahead on a project like this, be sure to get a bid from Newport News. Whether it's penstocks, butterfly valves, pumps or turbines, you'll get the benefit of the modern plant methods and production facilities of one of the country's oldest and largest builders of water power equipment.

Engineers... Desirable positions available at Newport News for Designers and Engineers in many categories. Address inquiries to Employment Manager.

Newport News
Shipbuilding and Dry Dock Company
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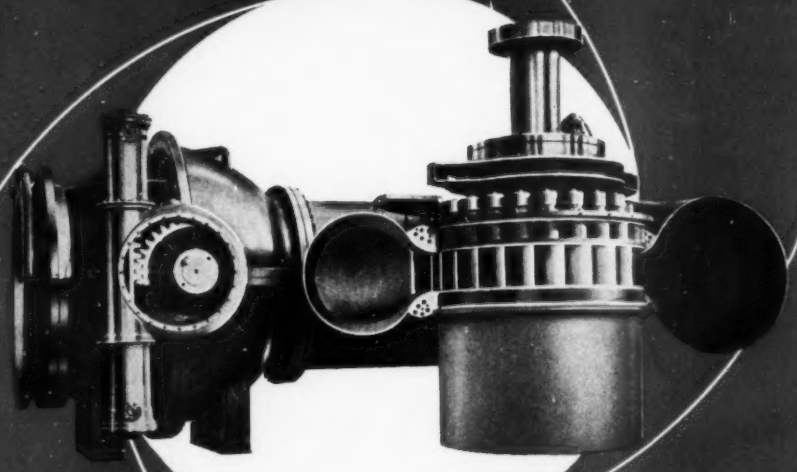
COMPLETE EQUIPMENT FOR WATER POWER PLANTS



Turbines of the Francis, Kaplan and Pelton type for various heads and outputs, transformers, generators, outdoor and indoor switch-gear, control-rooms, etc.

The world-known ŠKODA and ČKD trade-marks guarantee the first-class technical design and quality of equipment supplied by us. We give integral guarantees for complete deliveries.

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facing the runner hub with stainless steel "Bricks"

The first industrial unit driven by tidal power

The world's largest "bulb" unit runner

This "upstream-bulb" axial unit can work as a turbine or pump, irrespective of flow direction

output : 12 240 HP (metric)
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speed : 88, 25 r. p. m.
runner diameter : 5, 80 m

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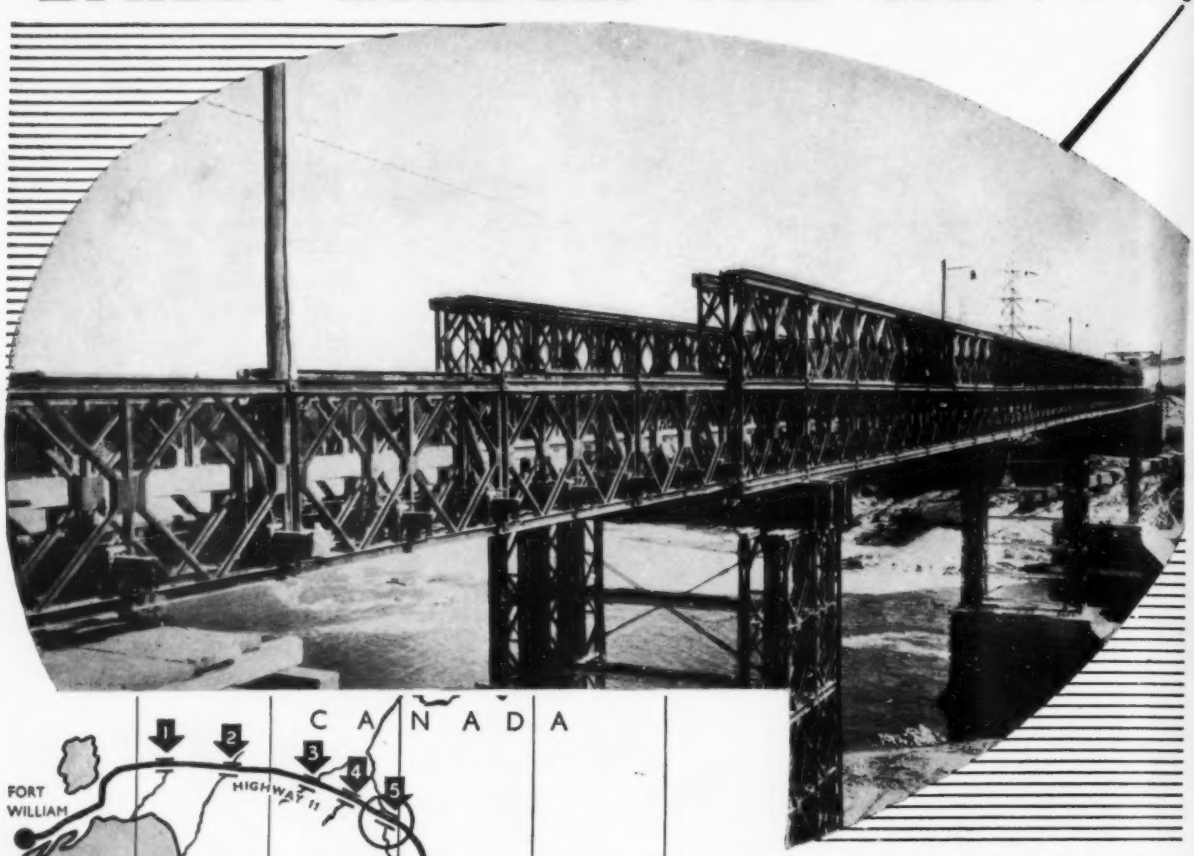

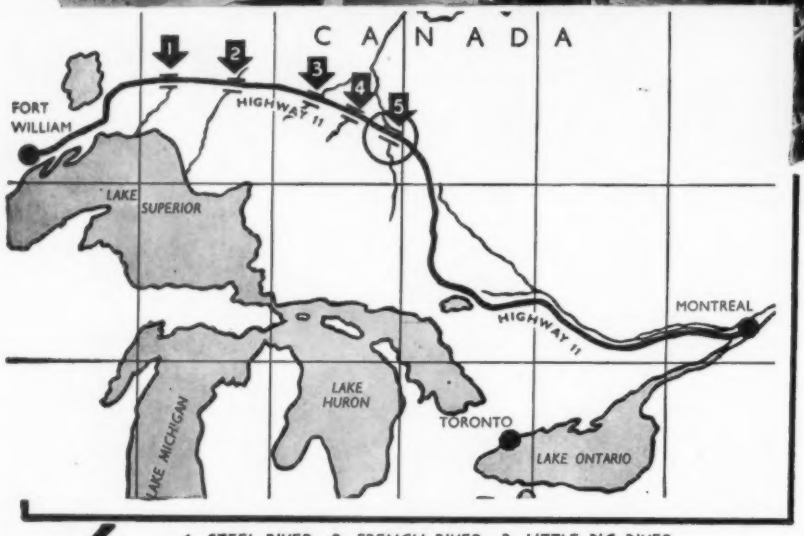

1. STEEL RIVER. 2. FRENCH RIVER. 3. LITTLE PIC RIVER.
4. KAPUSKANG RIVER. 5. MATTAGAMI RIVER.

PHOTO. BY COURTESY: THE DEPARTMENT OF HIGHWAYS—ONTARIO.

The Bailey Bridge—550 ft. long—across the Mattagami River, is just one of the many in constant use by a large volume of traffic on Highway II—part of the Trans-Canada Highway.

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Full information on this or any other project requiring Bailey Bridging is readily available, from:

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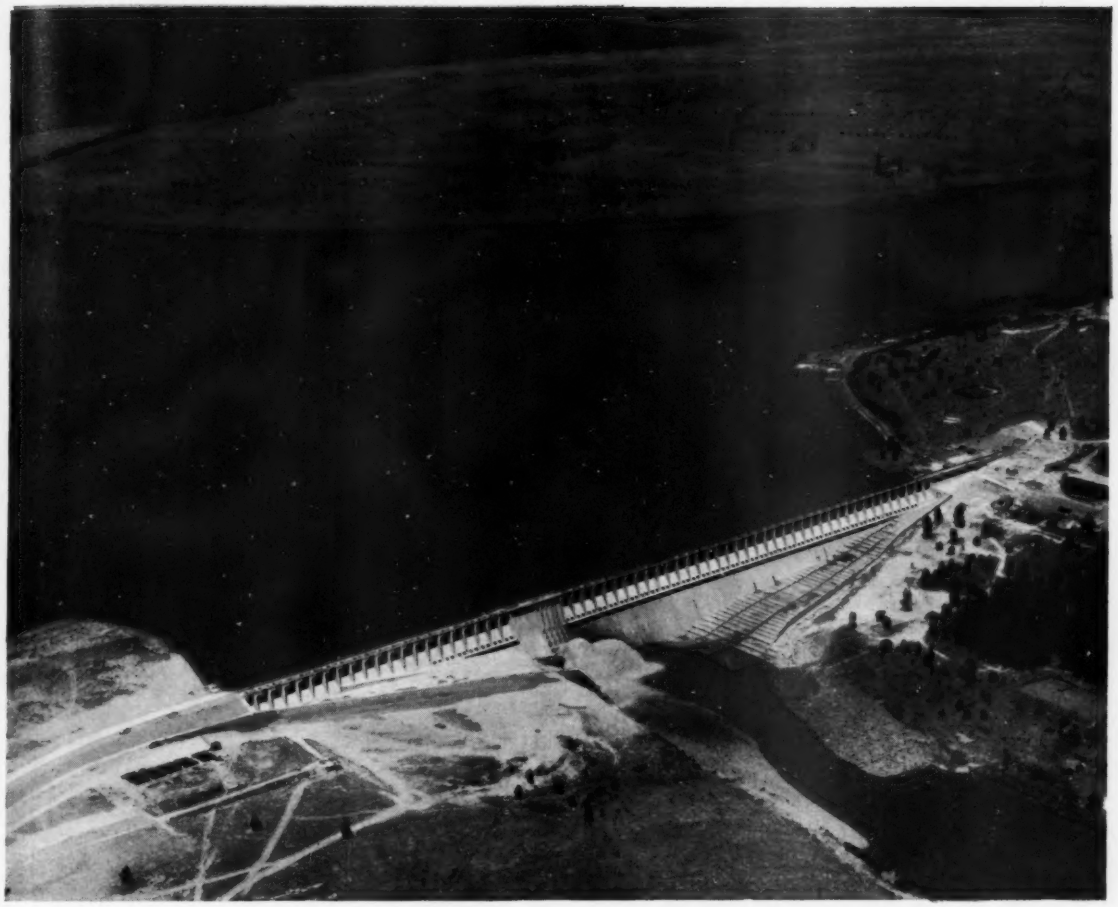

South Africa's Vaal-Dam is the largest man-made reservoir in the Southern Hemisphere.

Situated about 60 miles south of Johannesburg, the Vaal-Dam is almost half a mile wide. Its height was recently increased to a towering 180 feet.

Rheinstahl UNION Brückenbau AG. (formerly Dortmunder UNION Brückenbau-AG.) designed and manufactured the 78 spillway and emergency gates and supervised their installation into the dam.

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In the field of hydro-engineering we design and manufacture:

Sluice gates of all types for dams and weir plants, including mechanical equipment – safety gates – lock gates – ship lifts – penstocks for hydraulic power plants.

RHEINSTAHL UNION BRÜCKENBAU AG · DORTMUND/WEST GERMANY

440 B.H.P. UNDER 114 FT. HEAD ---

--- AGAIN AN ARMFIELD TURBINE

Illustration reproduced by kind permission of the North of Scotland Hydro-Electric Board. Consulting Engineers, Messrs. Kennedy & Donkin. Induction Generator, Messrs. Bruce Peebles & Co. Limited.

THE ARMFIELD HYDRAULIC ENGINEERING CO. LTD.

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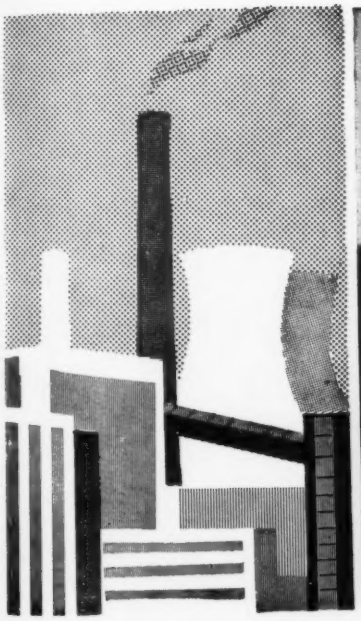
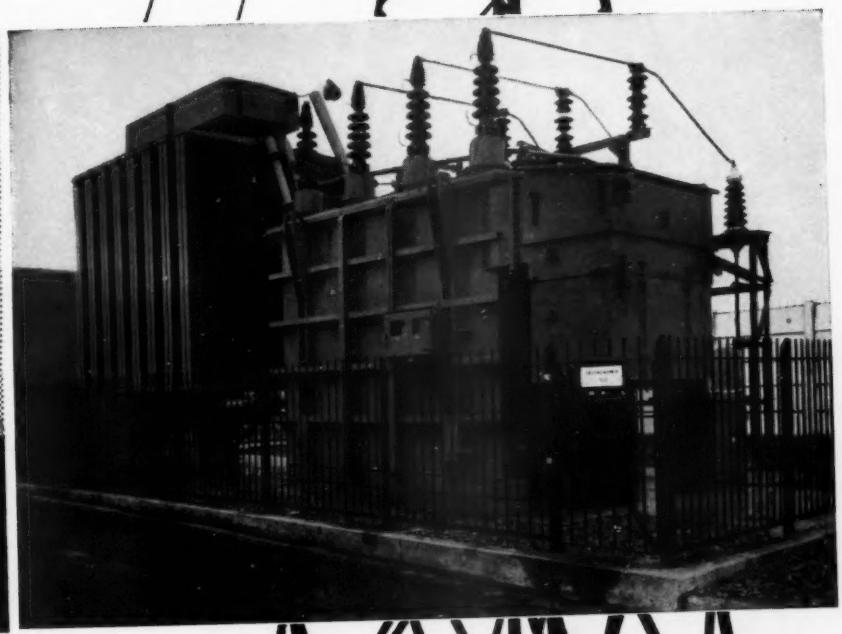
YORKSHIRE *transformers*

serve the power supplies of Great Britain





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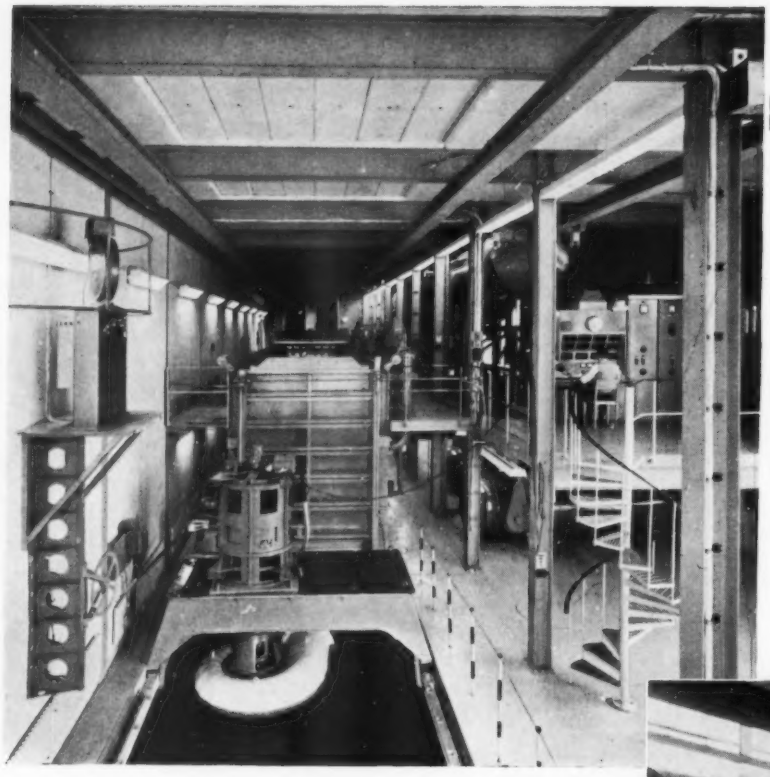
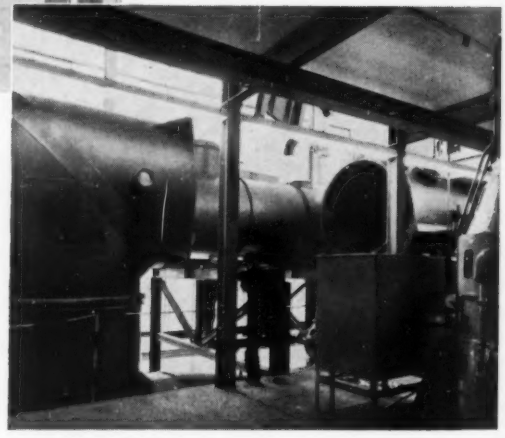


The main plant in the new laboratory is the large flume through which water flows to the turbine model.

Erection of the cavitation tunnel. The tunnel is intended for tests with large turbine models of Kaplan or propeller type.



KMW's new Turbine Laboratory at Kristinehamn -one of the best equipped in the world

The water power of the world is being exploited at an ever increasing rate. Turbines are being further developed and new types are appearing. The size of the average unit is increasing and greater demands are placed on performance. This calls for constant research and development work.

In this connection KMW as turbine manufacturers are well to the fore and for a long time past have maintained their position among the world's leading concerns in this field by extensive technical development work, above all in respect of the hydraulic design of the turbines. In order to intensify this activity still more, a completely new hydraulic laboratory has recently been put into service. The stationary equipment consists at present of three main units: an open flume circuit, where large model turbines can be tested under a head of 4 m, and two separate cavitation tunnels. One of the tunnels is intended for tests with models of high pressure turbines under heads up to 100 m, while the other, which like the flume has been proportioned for large scale models, is adapted for tests with low heads and large volumes of water. Controls and instrument readings are centralized. The measuring equipment is to a large extent electronic and permits great accuracy and rapid tests.

AB KARLSTADS MEKANISKA WERKSTAD
KARLSTAD - SWEDEN

Representatives in Canada: A. Johnson & Co. (Canada) Ltd.,
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KMW

St. Fillans Power Station
Consulting Engineers:
Sir M. MacDonald & Partners

underground power stations

Ceannacroc Power Station
Consulting Engineers:
Sir W. Halcrow & Partners

The illustrations show views of the first two major Underground Power Stations to be commissioned in the British Isles. Both of these stations were constructed by the Mitchell Construction Co. Ltd. as part of the numerous contracts carried out by them for the North of Scotland Hydro-Electric Board.

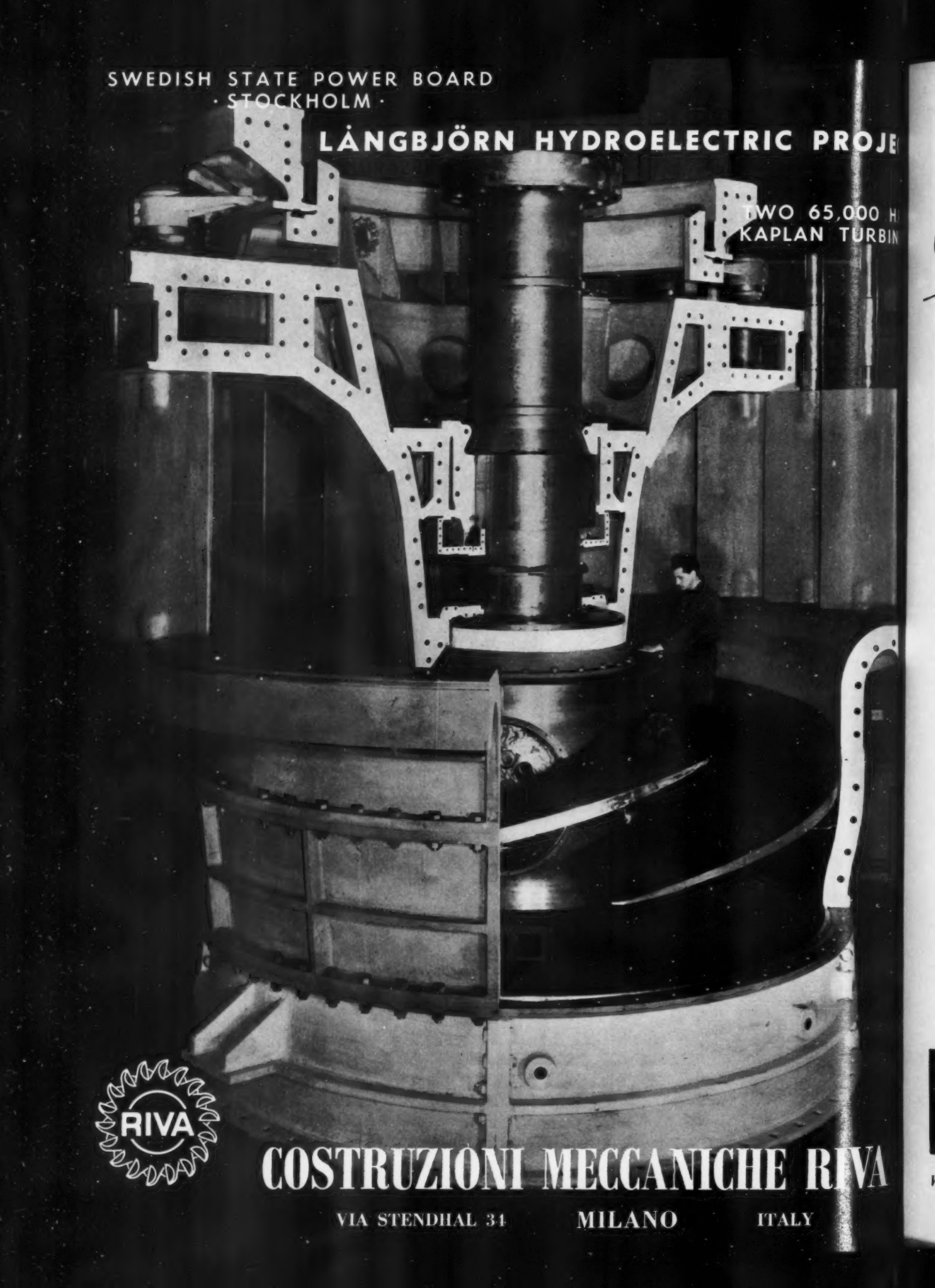
MITCHELL CONSTRUCTION

building and civil engineering contractors

THE MITCHELL CONSTRUCTION COMPANY LTD

Wharf Works, Peterborough

P.3051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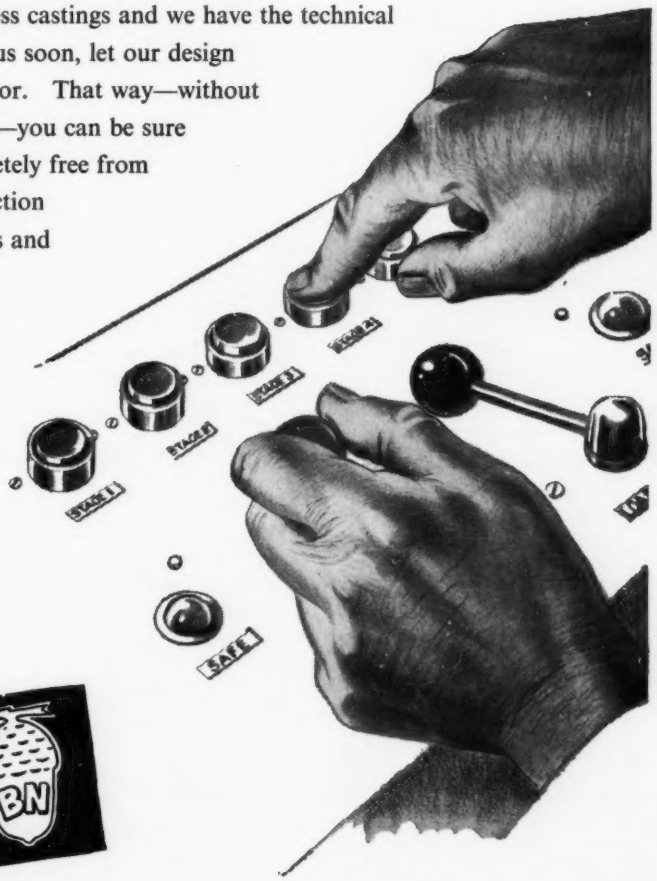

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in phosphor-bronze, gun-metal, aluminium-bronze, manganese bronze, and light alloys. Specialists in high-tensile aluminium-bronze castings, centrifugal-cast wheel blanks, shell moulded castings, and chill-cast rods and tubes. Continuous cast phosphor-bronze bars up to 12 foot lengths.

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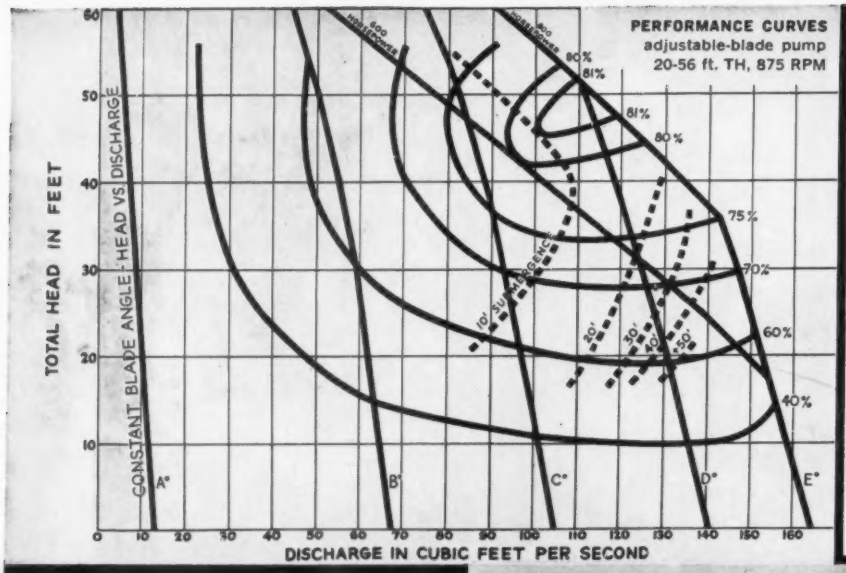
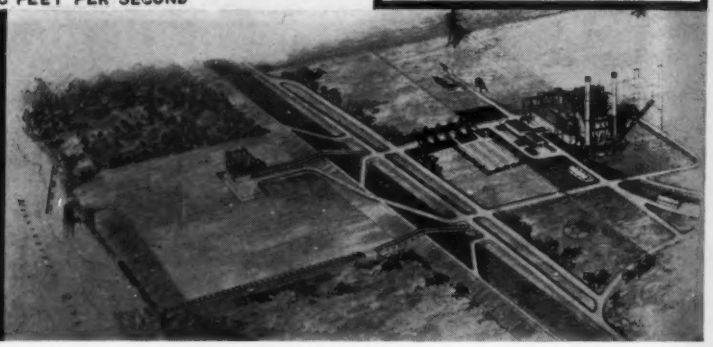


Performance curves of the A-C adjustable-blade axial flow pumps for Willow Glen illustrate their extreme flexibility. Pump operation is not restricted to a single head-discharge curve as is the case with fixed-blade pumps, but provides any discharge and head combination within the limits of motor horsepower and proper submergence.

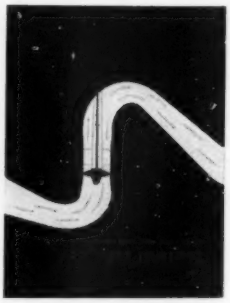


Stone & Webster Engineering Corp. is designing and constructing the Willow Glen Plant at St. Gabriel, La. on the Mississippi River for Gulf States Utilities Co.

Flexibility and efficiency make Allis-Chalmers adjustable-blade pumps choice for Willow Glen

Two 30-inch Allis-Chalmers adjustable-blade axial flow pumps will be installed to provide condenser water for Unit #1 at the new Willow Glen Power Station. To meet requirements at minimum river level, with water temperatures that vary between 39°F and 90°F, the pumps are designed to deliver a total of 76,000 gpm against a 54-foot total head.

Extreme variation of suction pool elevation and the flexible condenser operation required for this station made adjustable-blade pumps the logical and economical choice. A-C adjustable-blade pumps attain relatively high efficiencies over a wide discharge and head range. This is accomplished by varying the pitch of the impeller blades while the pump is operating at constant speed. This adjustability keeps pumping costs at a minimum by combining low starting torque with high average efficiency.



Pump Bulletin 165 will give you complete information on high capacity axial flow pumps. To get your copy, write to Allis-Chalmers Manufacturing Co., Hydraulic Division, York, Penna.

Hydraulic Division RESEARCH · DESIGN · HYDRODYNAMICS · ENGINEERING · FABRICATION

Hydraulic Turbines & Accessories • Pumps • Liquid Heaters

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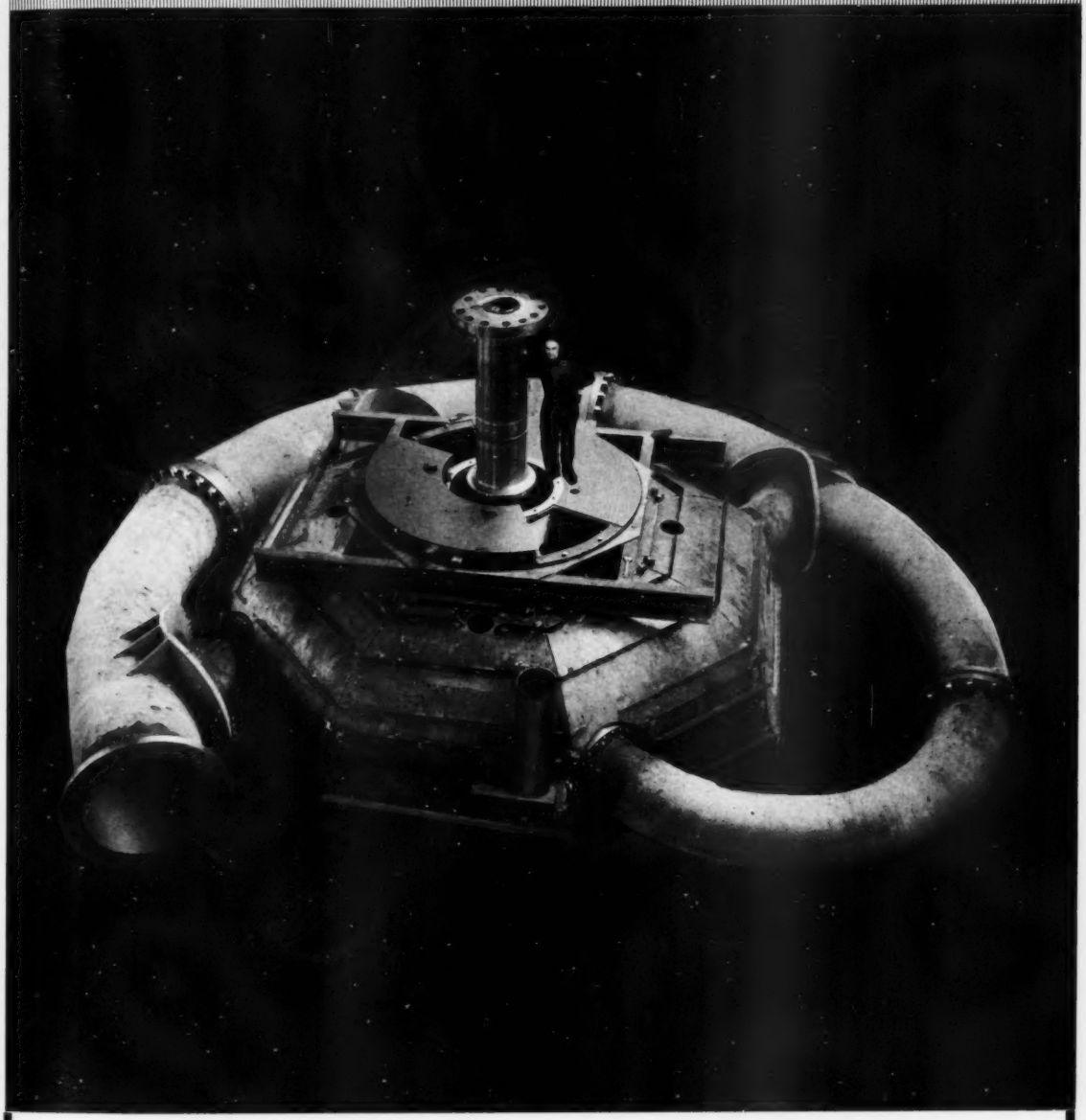
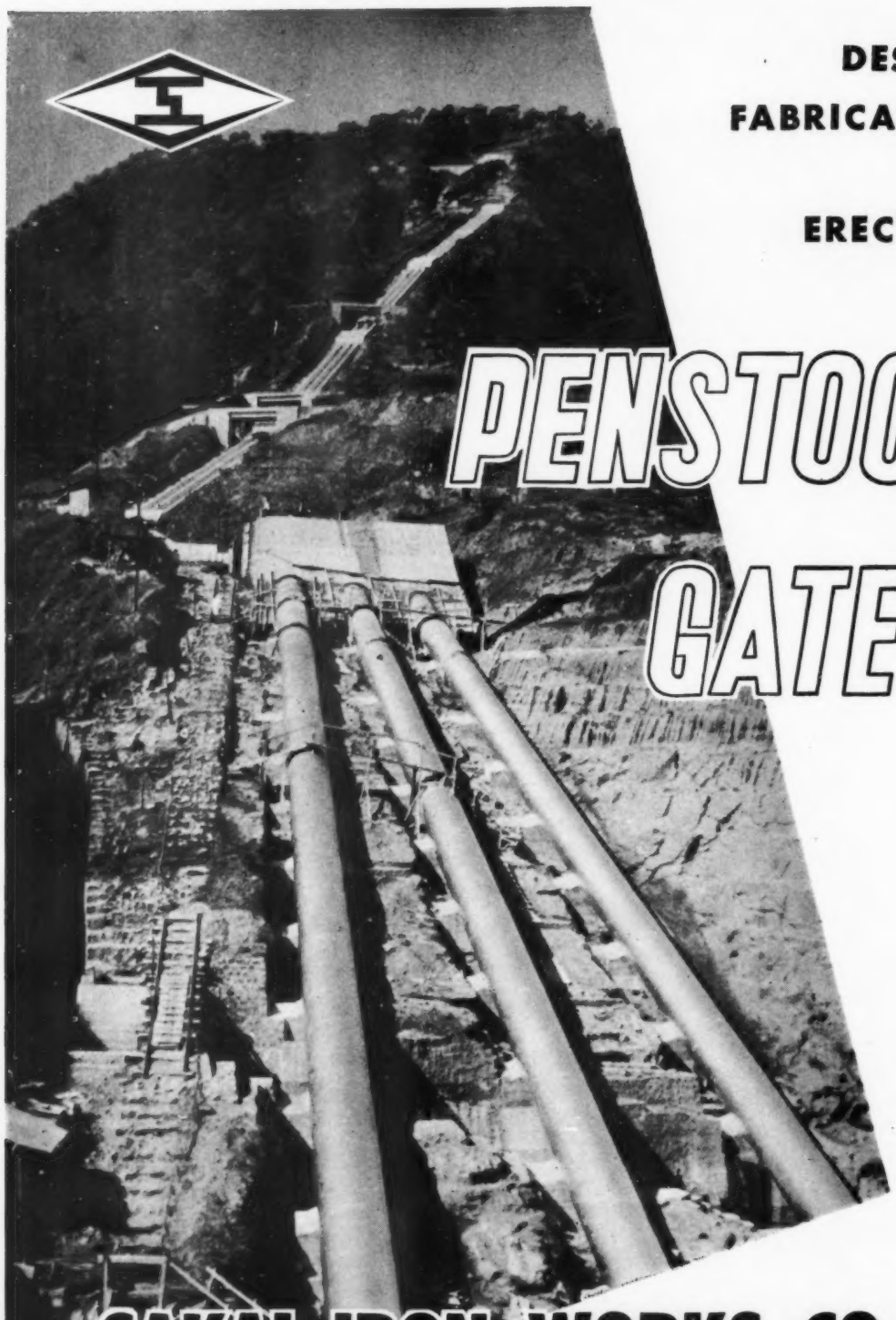


HYDRAULIC TURBINES

–CHARMILLES ENGINEERING WORKS LTD., GENEVA–

TWO 88,000 HP VERTICAL SHAFT, FOUR-JET IMPULSE TURBINES FOR BRAZIL



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SAKAI IRON WORKS CO., LTD.

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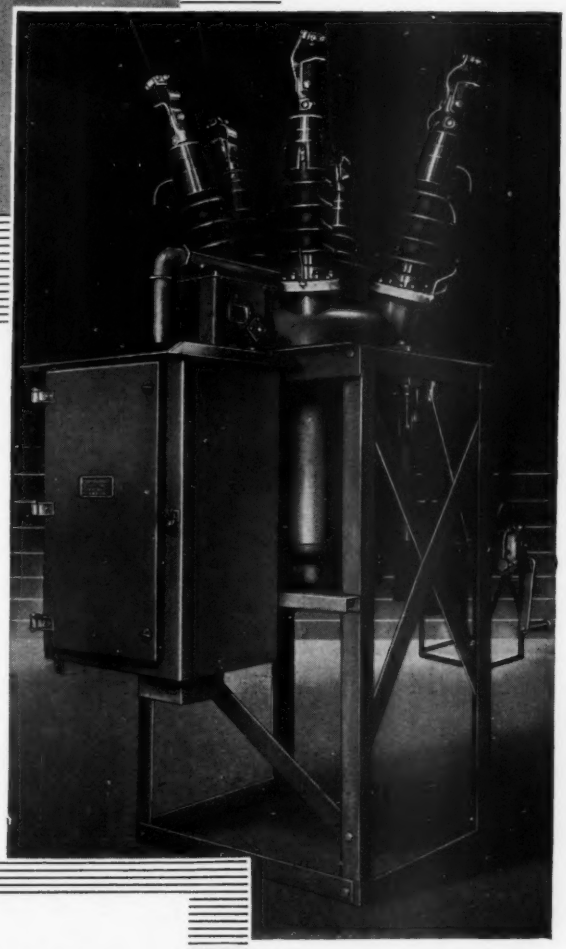
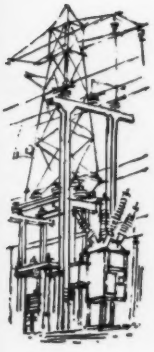
A1195

Why TYPE ROP 32 OUTDOOR SWITCHGEAR ?



When a decision must be reached concerning the installation of new, or replacement, OUTDOOR Switchgear the question may well be asked, "Why choose Type ROP.32?"
For the very good reason that this class of Switchgear has acquired a high reputation for itself by giving reliable service in many parts of the World, and in varied climatic conditions.

Readily adaptable to particular system requirements



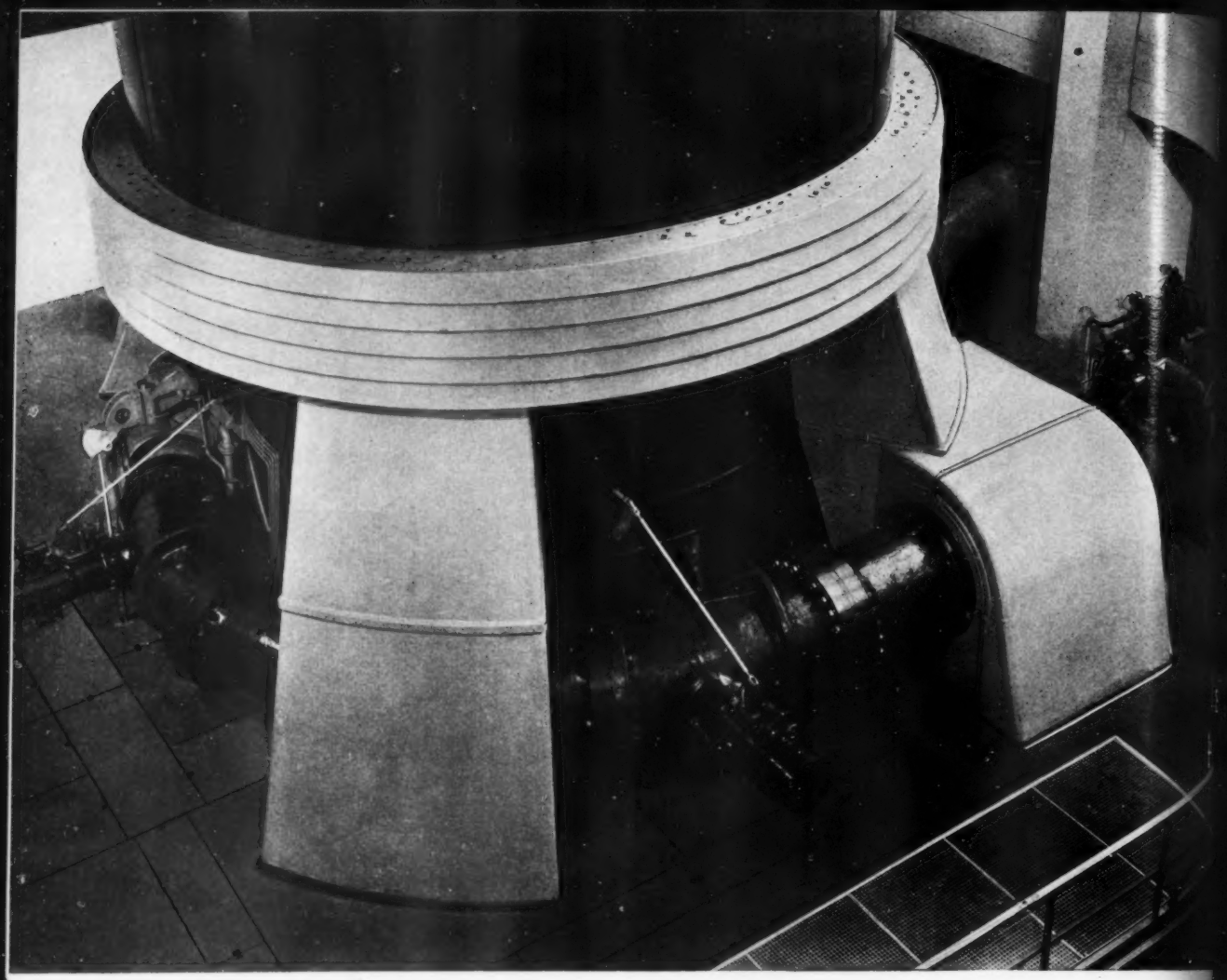
FOR 22/33 kV SERVICE

AEI

Manufactured at the Higher Openshaw Works of

Associated Electrical Industries Limited
SWITCHGEAR DIVISION

Higher Openshaw, Manchester · Trafford Park, Manchester · Willesden, London



VOITH

TURBINES · STORAGE PUMPS · TORQUE CONVERTERS

in the Lünersee Pumped-Storage Power Station, Vorarlberg (Austria)

Voith-Heidenheim have supplied:

2 4-jet Impulse Turbines, each rated at 62,800 h.p. under a head of 3,220 ft.

2 Rotary Valves for the turbines, each 2 ft. 8½ in. inside dia.

2 5-stage Storage Pumps, power input 67,500 h.p. on each pump

2 Needle Valves for the storage pumps, each 2 ft. 7½ in. inside dia.

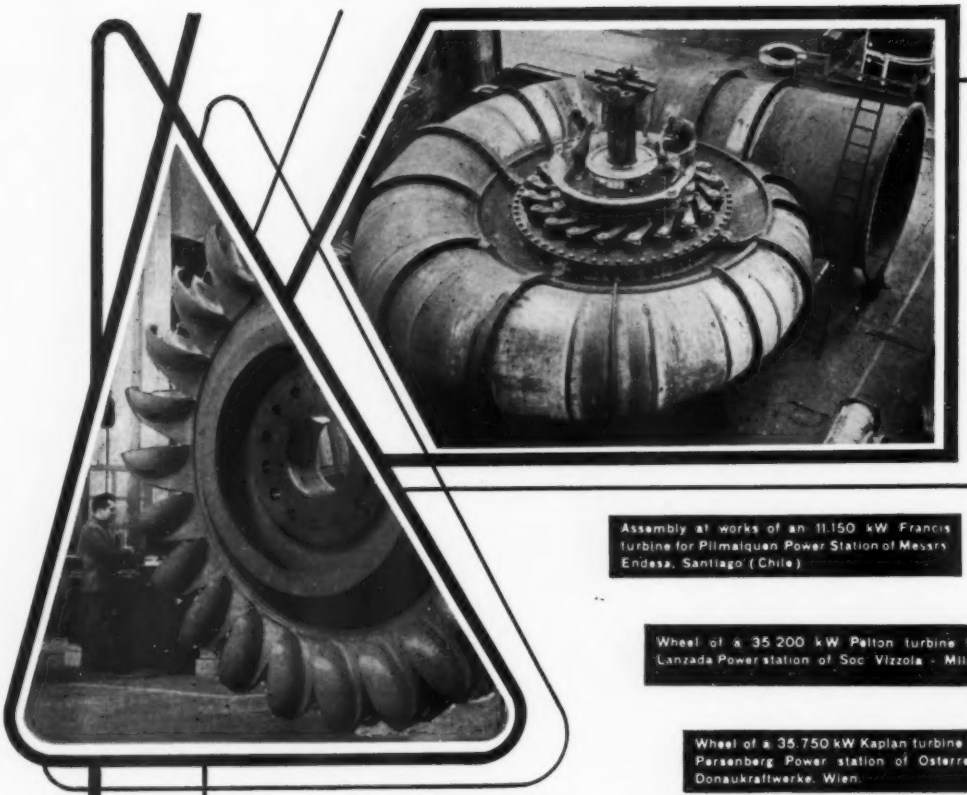
5 Synchronising Torque Converters with Gear Couplings for driving up and rigid coupling of all 5 storage pumps. For this new torque converter type we could draw on extensive experience in the design and manufacture of hydraulic torque converters for use in diesel locomotives.

The ring main for the spears and the rotary valve for one of the turbines are shown in the above photo.

The photo on the opposite page depicts the synchronising converter at the top and the storage pump underneath.

J. M. VOITH GMBH · HEIDENHEIM (BRENZ) · GERMANY

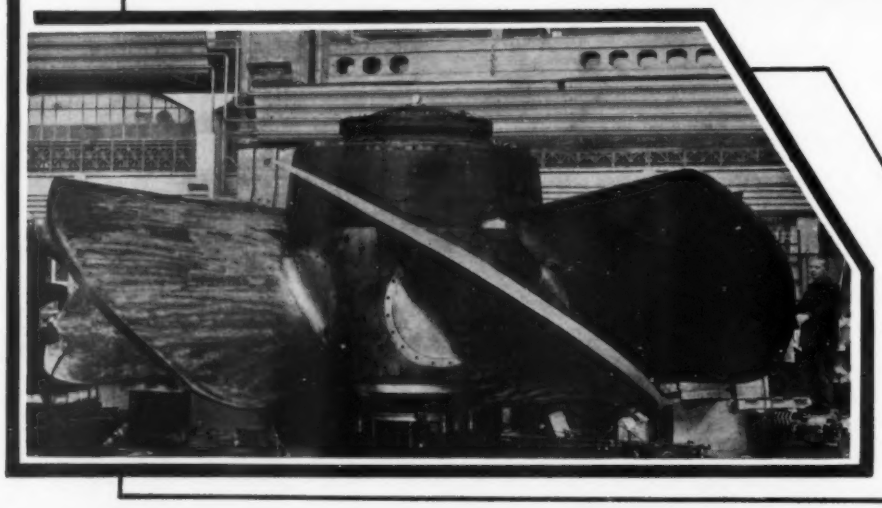
Complete hydro-electric plants



Assembly at works of an 11.150 kW Francis turbine for Pilmaiquen Power Station of Mesars Endesa, Santiago (Chile)

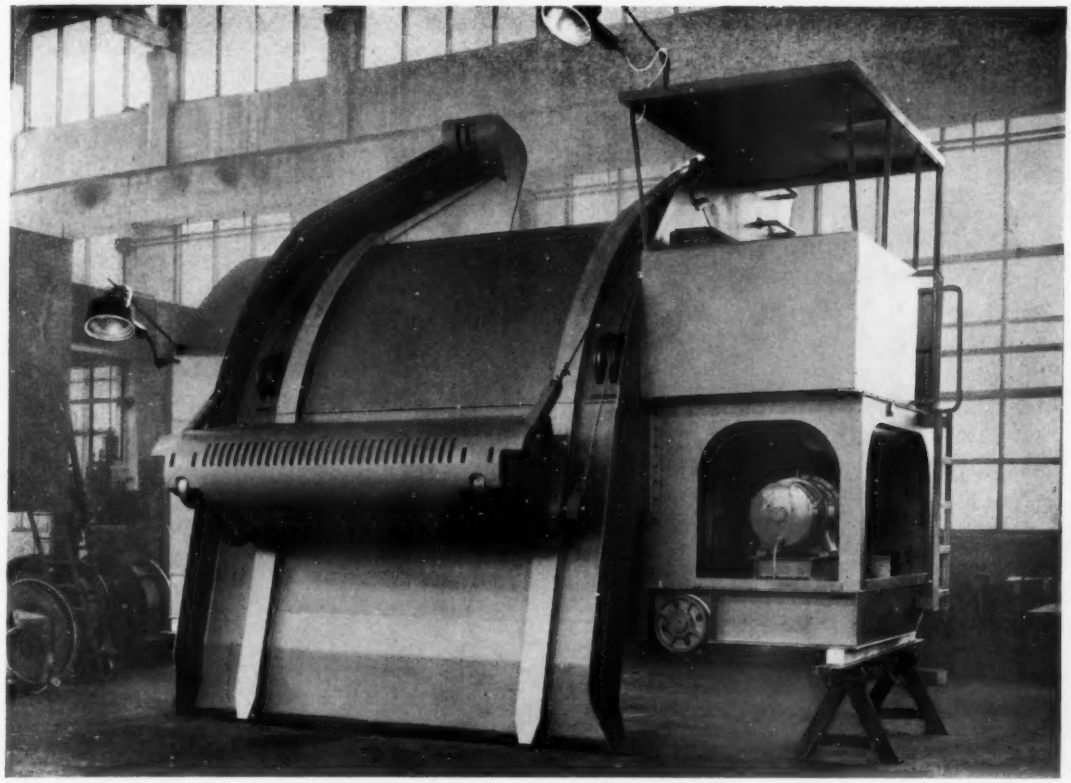
Wheel of a 35.200 kW Pelton turbine for Lanzada Power station of Soc Vizzola - Milan.

Wheel of a 35.750 kW Kaplan turbine for Ybbs Persenberg Power station of Osterreichische Donaukraftwerke, Wien.



ANSALDO-SAN GIORGIO
GENOVA

HYDRAULIC STEEL STRUCTURES



Travelling, automatic screen cleaning machine for Power Station Rio Caroni Macagua No. 1:—

Cleaning width	2.1 m
Width of rake	32 m
Travelling speed	13.5 m/min
Lifting and lowering speed	16.3 m/min

●

DESIGN AND CONSTRUCTION:

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Get the speed of a

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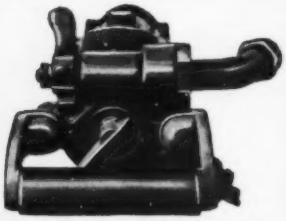
on your tunnel work

Packing a tremendous punch, the new 50 lb. weight "Tornado" drill combines the great power and speed of a column-mounted drifter with the ease-of-handling of a medium-weight sinker. Such power, achieved by advanced, go-ahead design has, however, not been obtained at the expense of reliability: the "Tornado" is an immensely rugged tool, with a rate of wear no greater than that of conventional tools of lesser performance.

Redesigned valve and airflow passages, together with a 3"-diameter short-stroke piston give a high power/weight ratio, ensure maximum transmission of power to the steel.



Easy-to-operate backhead control allows quick selection of water or air for emergency blowing.

The patented retainer makes assembly and operation extremely simple. A bonded rubber ring provides an excellent cushion and considerably reduces the possibility of steel breakage.

British designed and British built by **Consolidated Pneumatic**

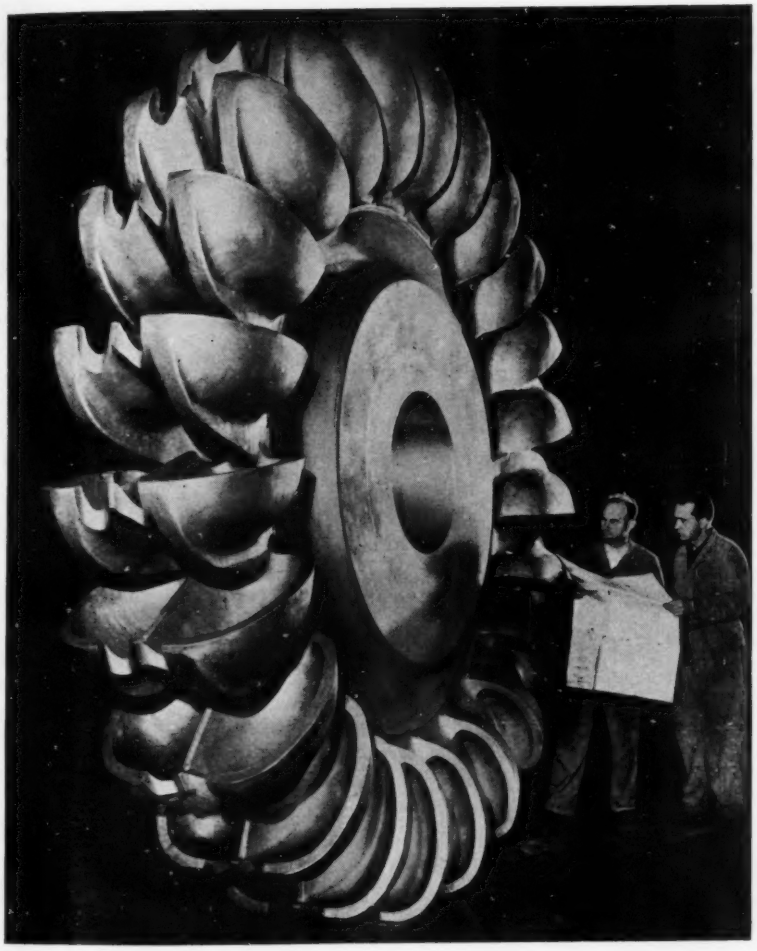
CONSOLIDATED PNEUMATIC TOOL CO. LTD · DAWES ROAD · LONDON · S.W.6

AZIENDA ELETTRICA MUNICIPALE, MILANO (ITALY)

GROSIO WATER POWER STATION

NORTH ITALY

2-107,000 kW. Vertical axis, four-jet PELTON units



Wheel of one of the two PELTON units

Output each:-
107,000 kW.

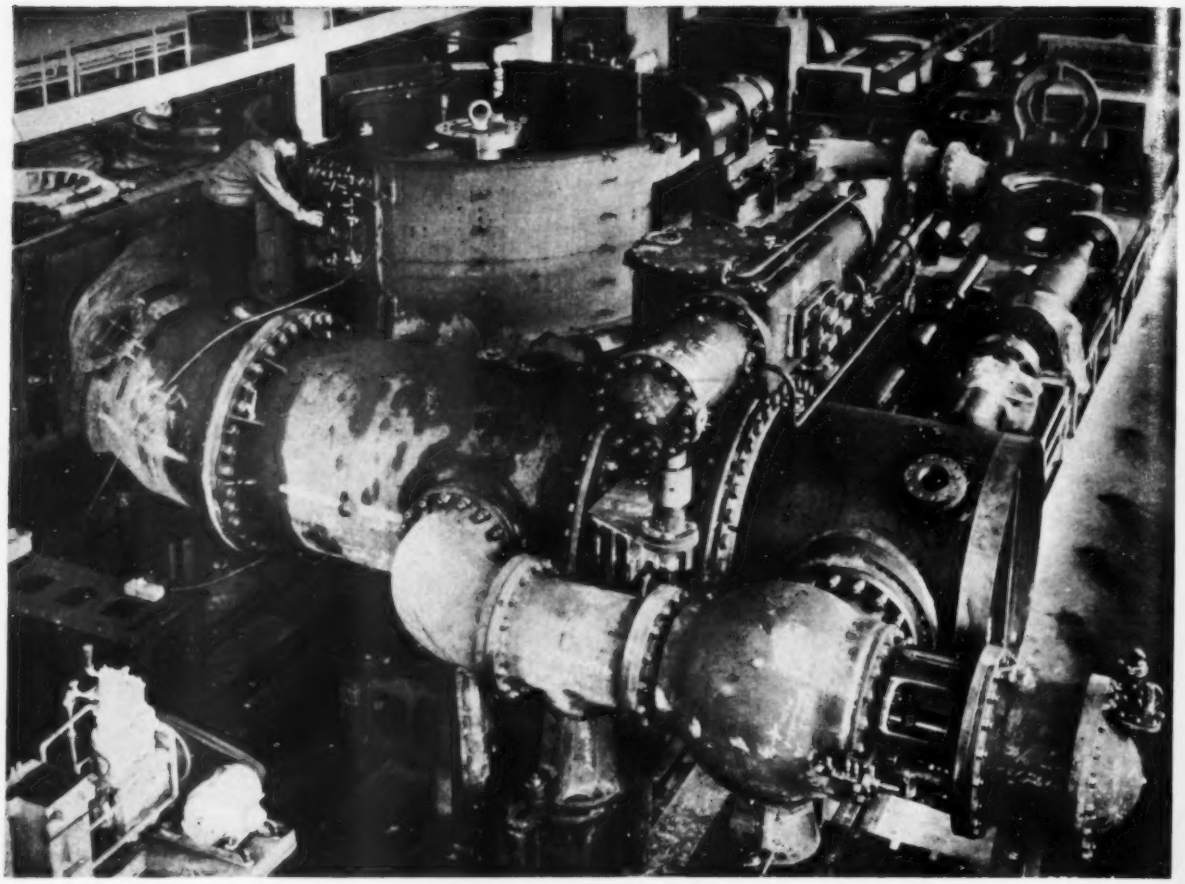
Available head:-
600 mts.

Discharge:-
20,350 lts/sec.

Speed:-
333.33 r.p.m.

EUROPE'S HIGHEST OUTPUT PER UNIT

FRANCO TOSI S.p.a ★ LEGNANO (ITALY)



Hitachi builds Japan's first reversible pump turbine

Another advance in hydroelectric power generation for Asia was recorded with Hitachi's recent completion of the first reversible pump turbine in Japan. It was built for the Omorigawa Pumped Storage Power Station on the island of Shikoku.

This unit was designed to ensure efficient operation under conditions of fluctuating river flow. When power is generated in excess of grid requirements the generator is operated as a motor and the turbine as a pump, so storing water against peak demand and future shortage.

Particularly notable is its high head as a reversible pump turbine and widely variable operating conditions.

Main specifications of this unit are as follows :

	Normal Speed (rpm) ...	400
As a Turbine	Max. Output (KW) ...	12,200
	Effective Head (M) ...	116·85—74·3
As a Pump	Max. Discharge (M^3/sec.)	13
	Total Head (M)	92—127·8 M

Hitachi, Ltd.
Tokyo Japan

Cable Address: "HITACHY" TOKYO

POST INSULATORS for the Hirakud Dam project

S.P.P. Post Insulators were supplied for the 132kV. outdoor switchgear on the Hirakud Dam Project.

S.P.P. Post insulators have also been used on all the major hydro-electric projects in India, including the following:—

Damodar Valley Corporation
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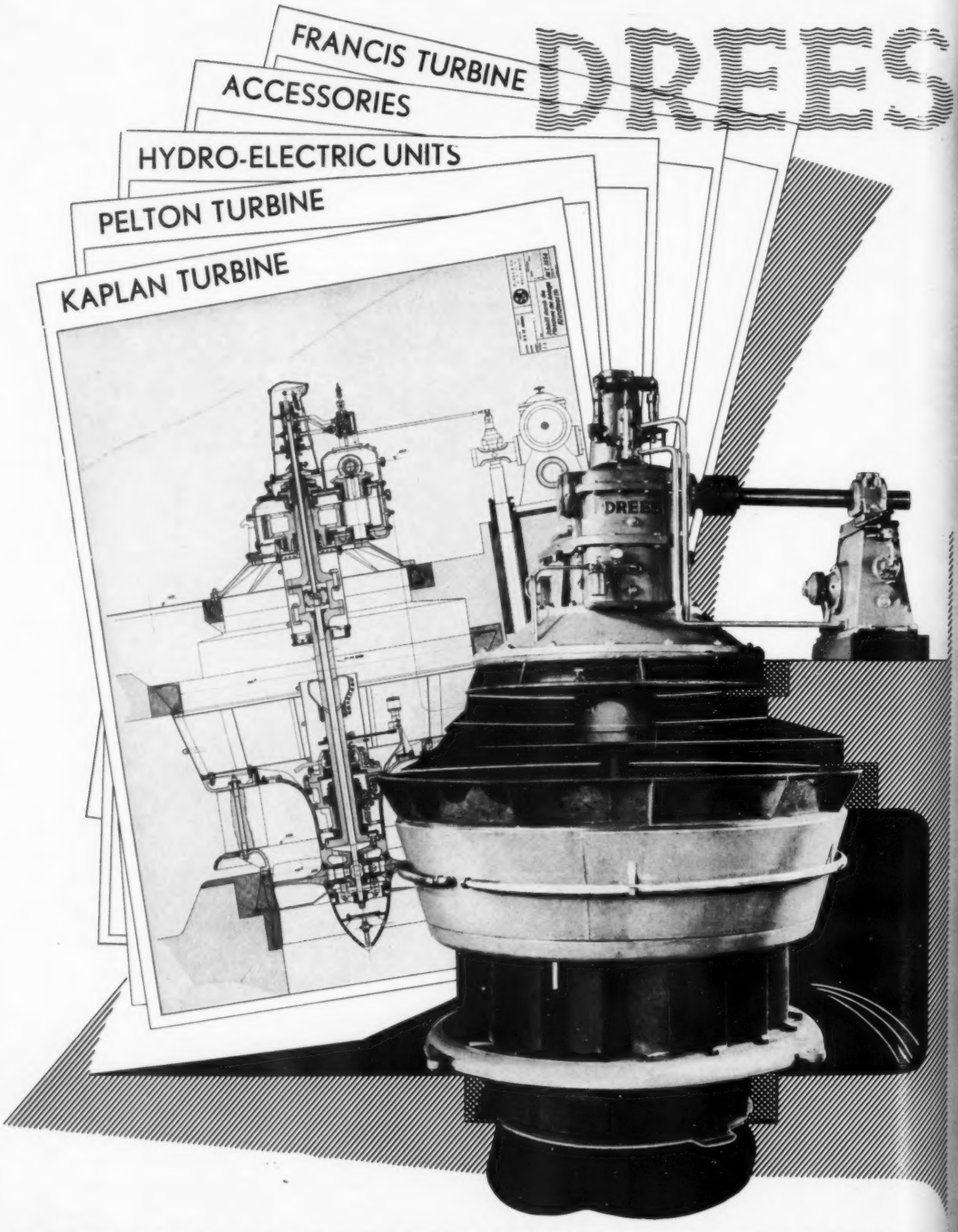

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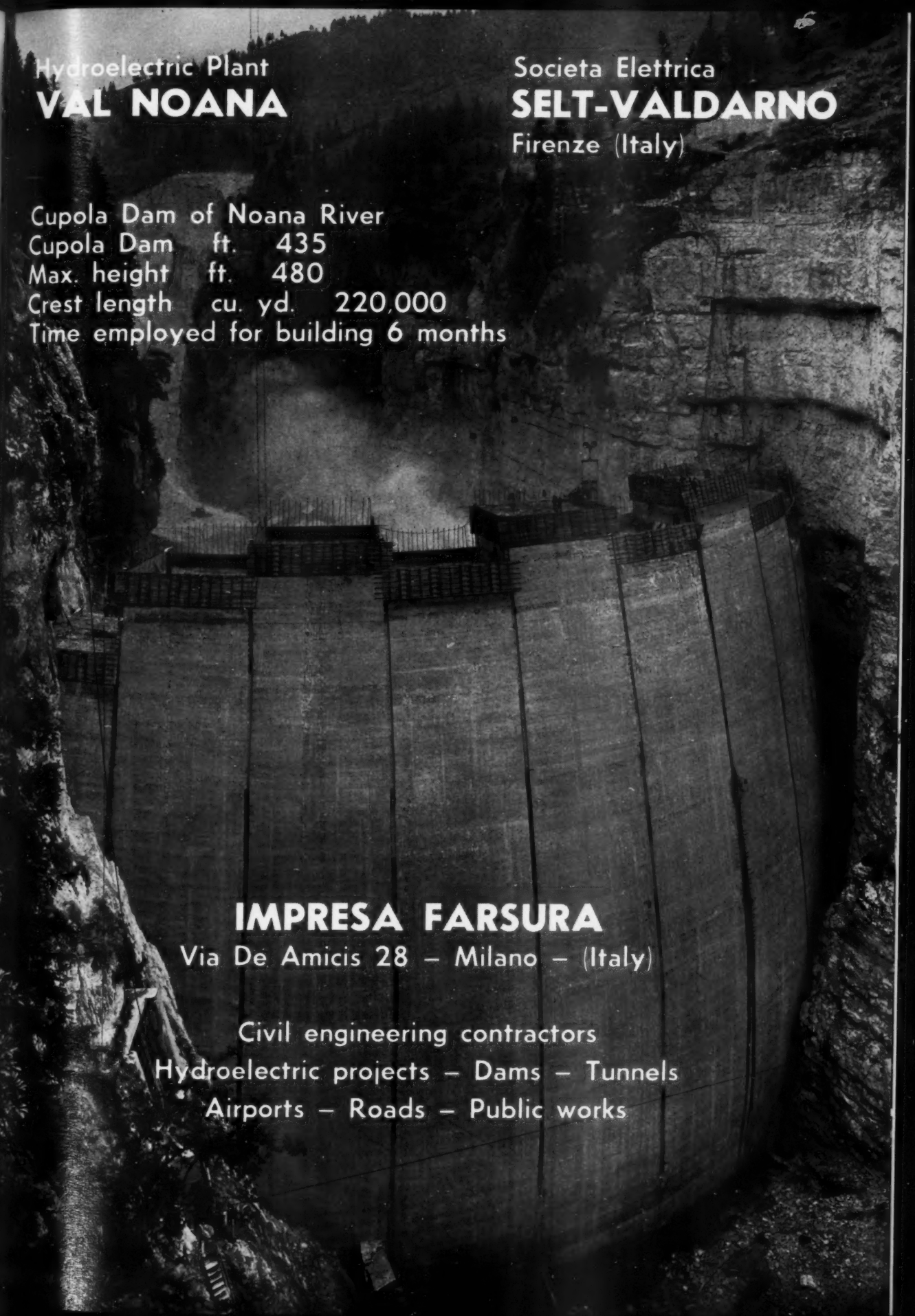
Hydroelectric Plant
VAL NOANA
Societa Elettrica
SELT-VALDARNO
Firenze (Italy)
Cupola Dam of Noana River
Cupola Dam ft. 435
Max. height ft. 480
Crest length cu. yd. 220,000
Time employed for building 6 months
IMPRESA FARSURA
Via De Amicis 28 – Milano – (Italy)
Civil engineering contractors
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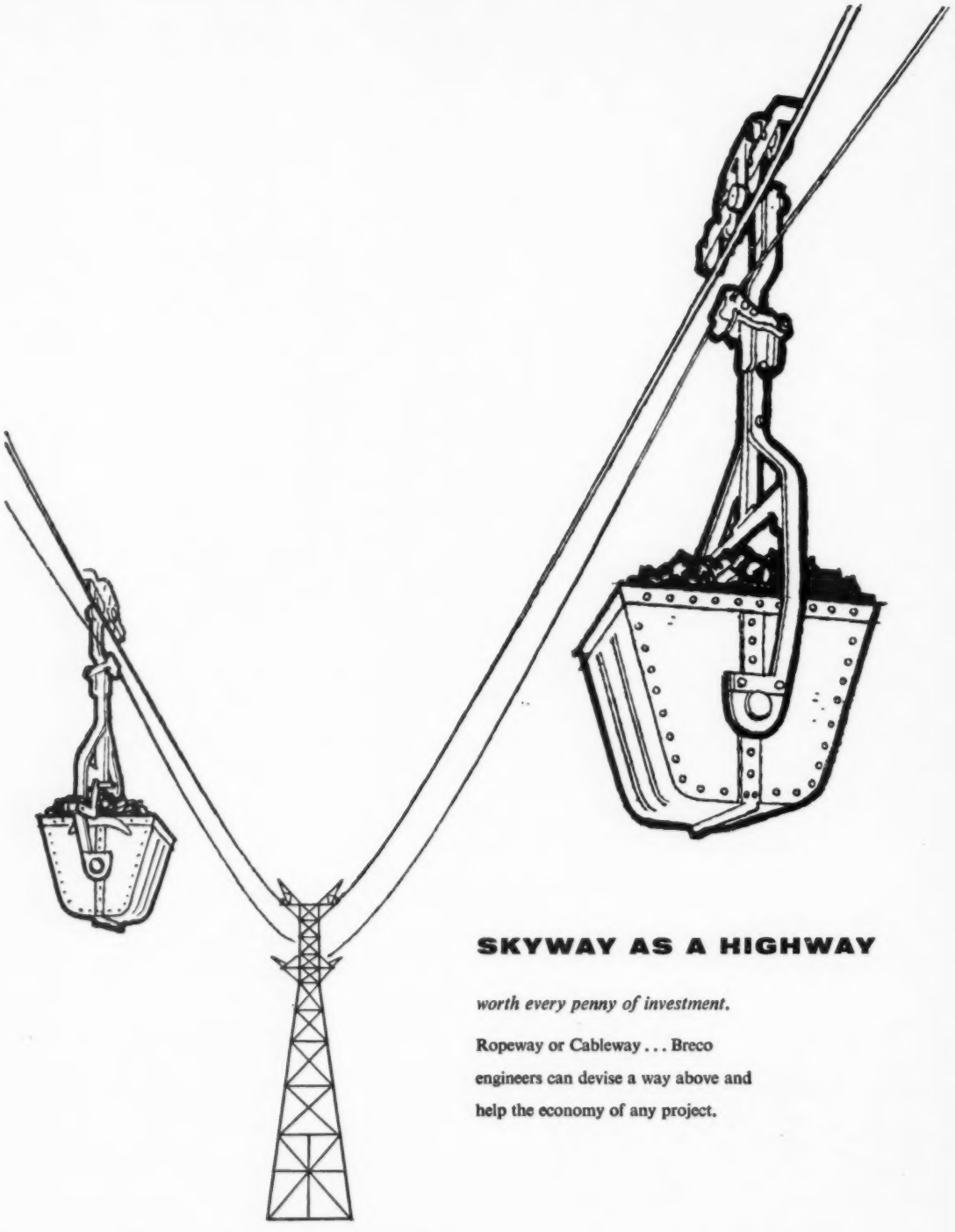

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Ropeway or Cableway . . . Breco engineers can devise a way above and help the economy of any project.

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Study, planning, design and erection of complete:

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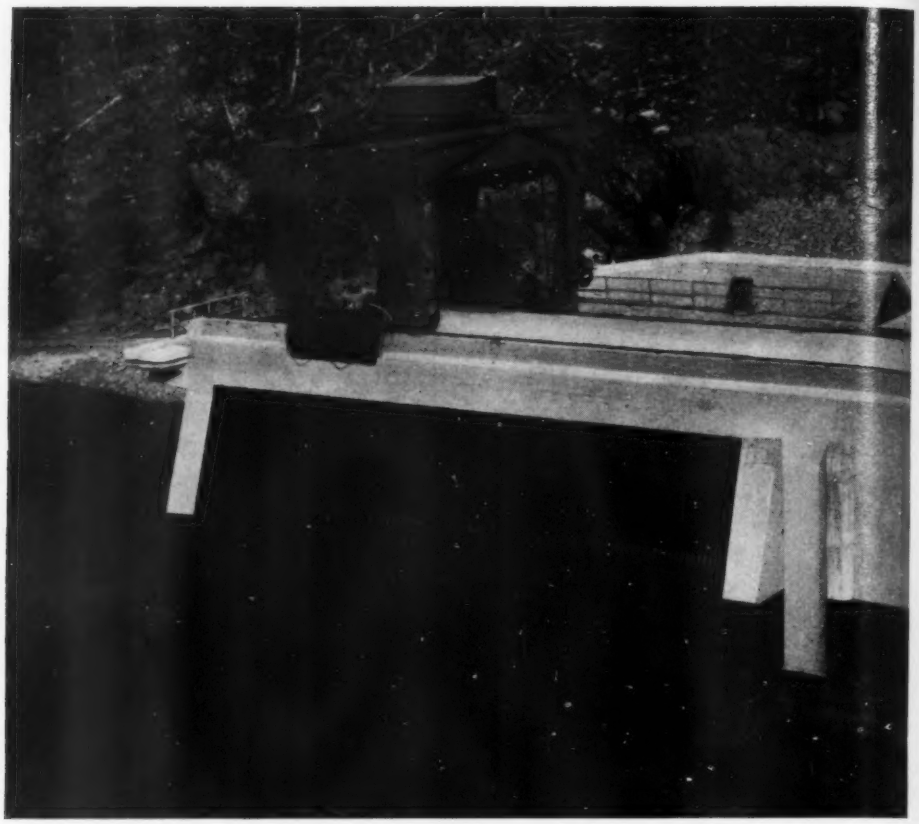
Twin pipe line in Switzerland for a service pressure of 1,600 lb./sq.in. in the course of erection



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for Intakes

of the built-up bar type in fixed or removable styles for tunnel or turbine intakes, to suit requirements.

Above is illustrated a large fixed screen at a tunnel inlet, served by a partial span Glenfield plough rake operated by a traversing crane. The other photograph reproduced shows removable screens on turbine intakes, and their handling crane which is equipped with an automatic hooking beam.

Glenfield

GLENFIELD & KENNEDY LIMITED KILMARNOCK

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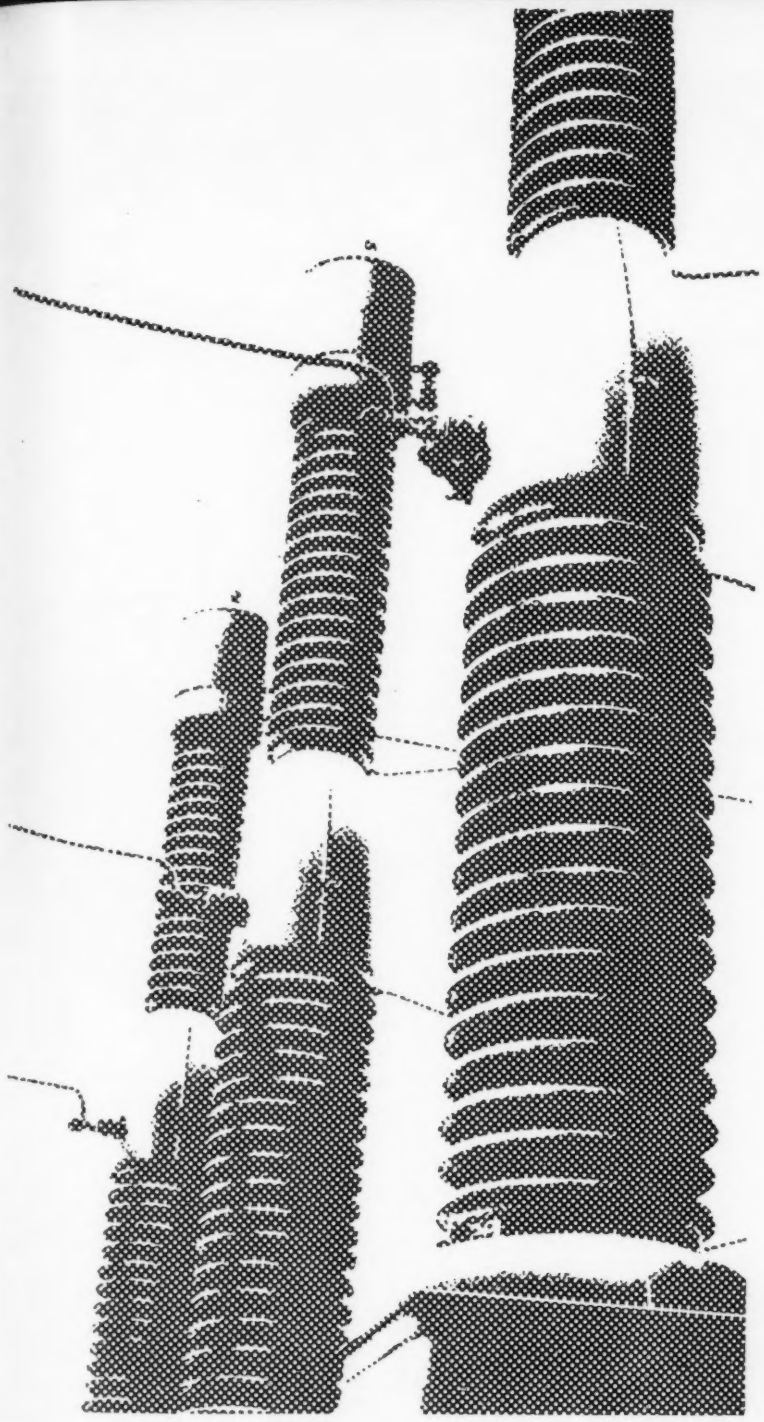

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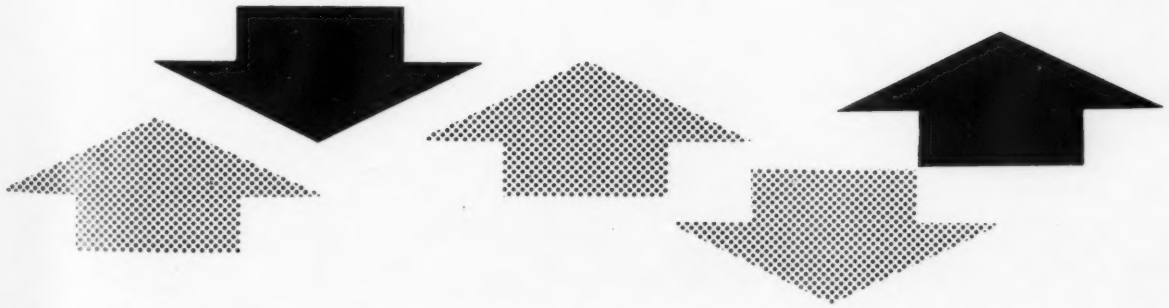

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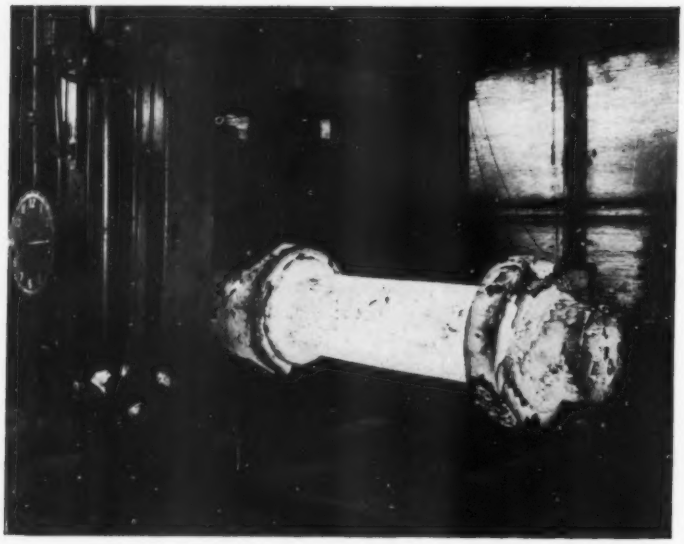


For many years ESC has been the leading supplier of steel forgings to many vital industries. Forgings in weights up to 175 tons are manufactured in our high quality carbon and alloy steels—single piece engineering units produced from ingots weighing up to 275 tons—and

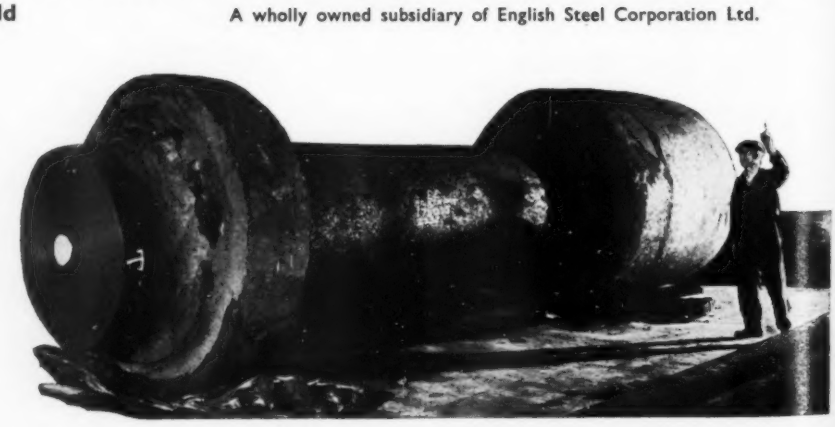
other forgings from ingots 30 cwt. and upwards—for all branches of engineering.

ENGLISH STEEL FORGE AND ENGINEERING CORPORATION LTD.

River Don Works, Sheffield

A wholly owned subsidiary of English Steel Corporation Ltd.

Illustrations show a forging operation under a 7,000 ton electro-hydraulic press, rough machined and black forged steel Turbine Shafts, 22′ 11″ long, 3′ 8″ diameter with 6′ 2″ and 6′ 4″ diameter couplings—weight as forged 111½ tons, rough machined 70 tons—for a modern hydro-electric power project.



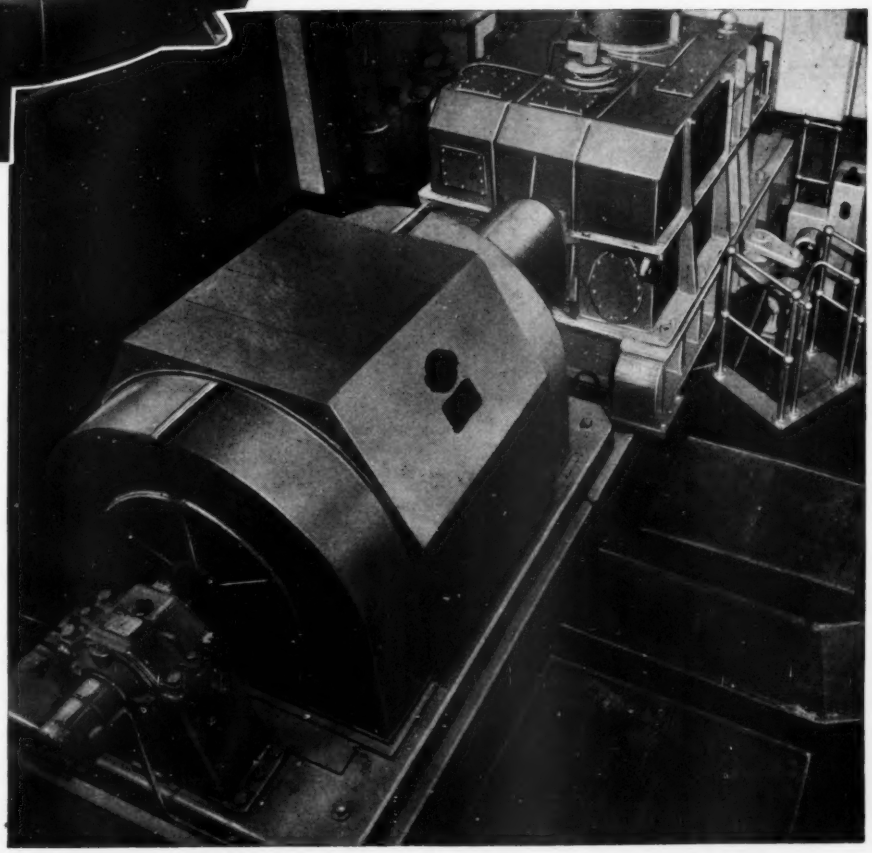
GILKES

ASYNCHRONOUS HYDRO-ELECTRIC UNITS for all heads and outputs

Suitable for remote controlled or fully automatic installations, the water turbine driven induction generator provides a simple and economic source of power for operation in conjunction with conventional synchronous plant.

Gilkes specialise in the manufacture of asynchronous hydro-electric plant and have a wide experience in the design of all types of unit.

Above:
A 48kW induction generator driven by a 71 horsepower GILKES Francis turbine. This unit is installed in the Lochay Fish Pass, part of the North of Scotland Hydro-Electric Board's Breadalbane Scheme.



Right:
The North of Scotland Hydro-Electric Board's Mullardoch underground power station, Glen Affric. This contains a 3,600 horsepower, vertical shaft GILKES Francis turbine driving a 2,400kW Bruce Peebles induction generator through a speed increasing gear unit.

GILBERT GILKES & GORDON LTD

WATER TURBINE & PUMP MANUFACTURERS

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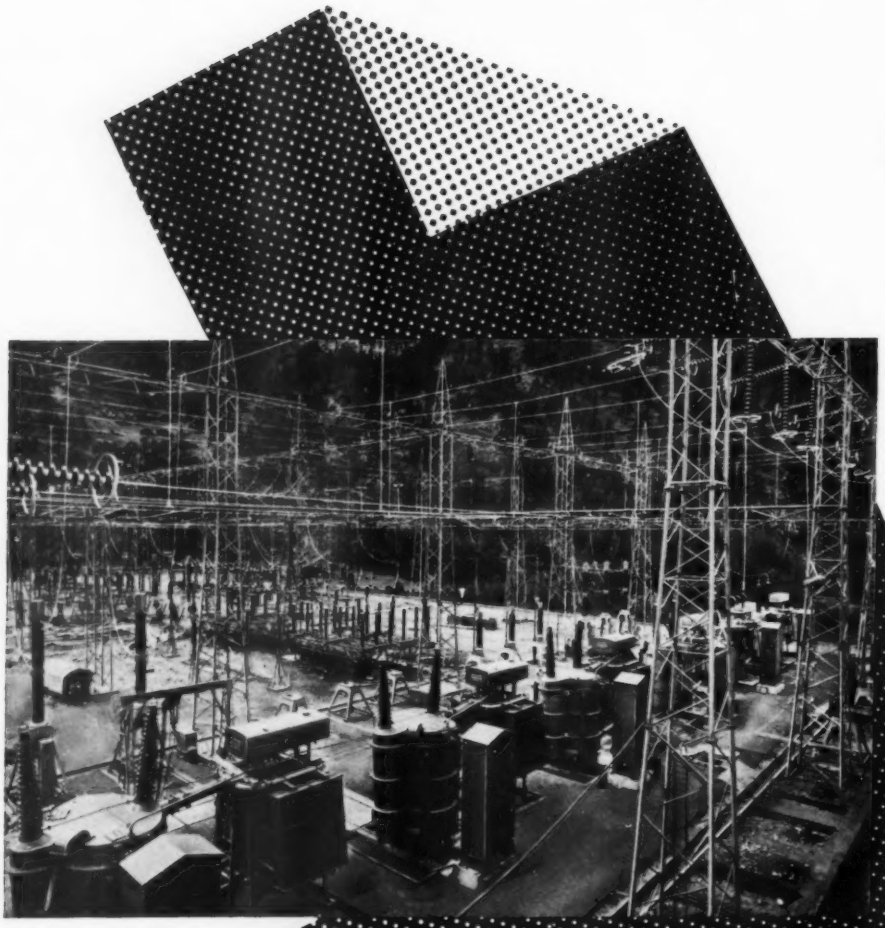

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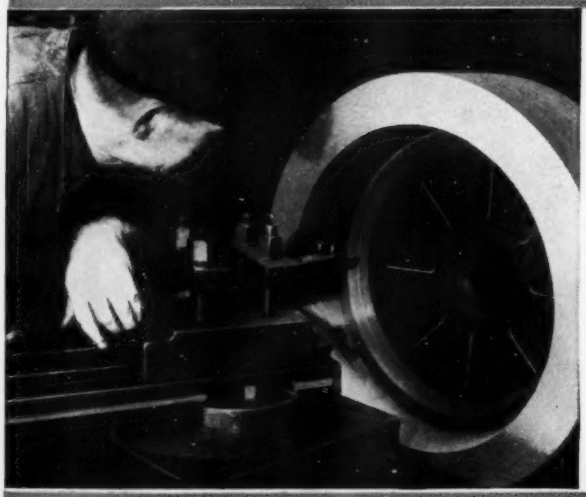
to any size you like

M & I have the largest stock of Micanite V-ring moulds in Europe. Many different types are available in a very wide range of sizes. We have supplied Micanite insulation for commutator V-rings up to 114" in diameter but this is not the limit of our capacity. If you have any problems, please take us into your confidence — we have a wealth of experience gained over more than half a century. Let us have your enquiries for V-rings.



A Micanite V-ring 40" in diameter, and moulded in one piece, manufactured recently for Harland & Wolff Ltd. for installation in No. 5 generator in the Union-Castle Mail Steamship Company's R.M.M.V. "Capetown Castle" (27,000 tons).

Moulds for V-rings are machined in our own factory.

We make every type of Micanite Insulation and, as with all M & I Products, the quality is second to none.

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Blackhorse Lane, Walthamstow, London, E.17. Tel: Larkswood 5500.
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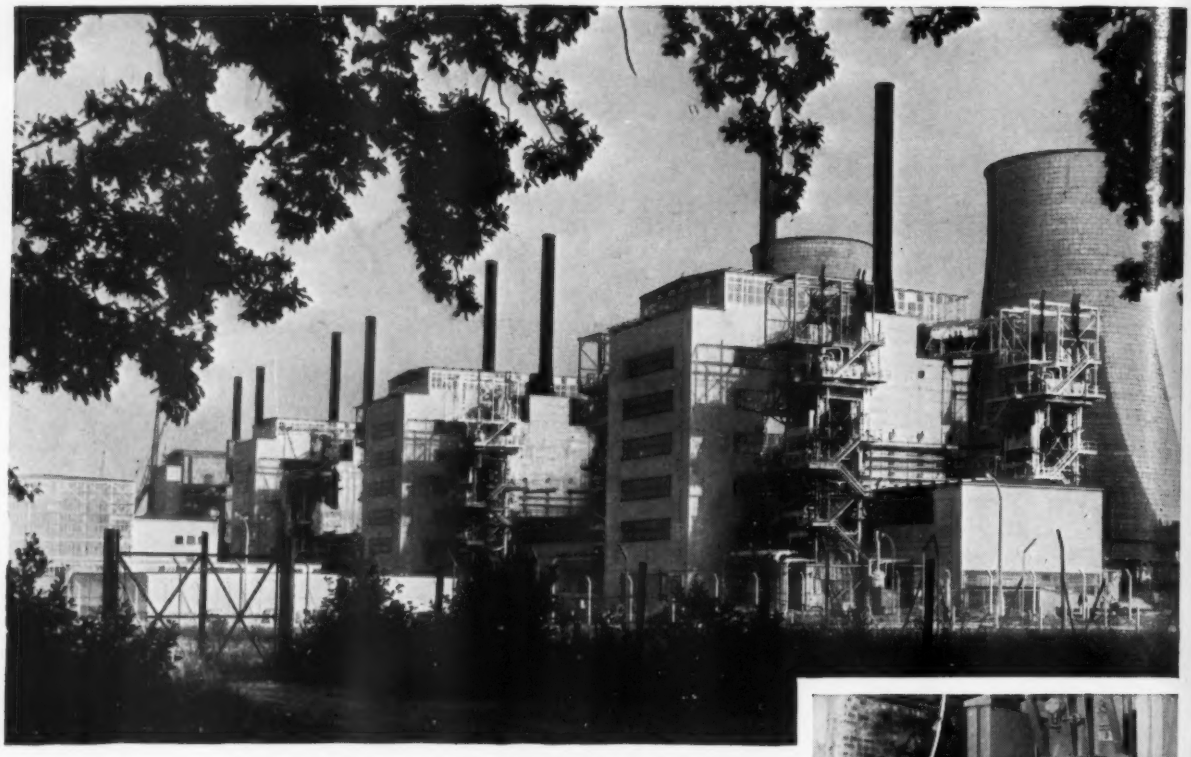

RIGHT: *Installing Henley single-core 33 kV cables in Turbine Hall Transformer Bays.*
BELOW: *Henley Control Cables rising to Reactor No. 1 Control Panels.*

Chapelcross opens . . .

Officially opened on 2nd May by the Lord Lieutenant of Dumfriesshire, the first of the four reactors at Chapelcross is already in operation. Plutonium is being produced and electricity is flowing to the grid. Integrating every aspect of this dynamic enterprise—from basement to pile-cap, turbine house to reactor building—are the "nerves" of Chapelcross . . . the vital electric cables that must meet the vast power requirements and the minute, intricate needs of the complex warning system. All the power and service cables at Chapelcross are Henley Cables. Henley's, together with their sub-contractors, Messrs. T. W. Broadbent of Huddersfield (who are responsible for instrument wiring, M.I. cable and conduit work) have installed over 160 miles of cables in all—a contract valued at £½ million. Thus HENLEY cables are playing their part in Britain's plutonium production programme and, as Chapelcross achieves maximum output, Henley cables will channel 140 MW of power into the national grid. Chapelcross is a proud project—and Henley's are proud of their part in it.

CONSULTANTS: MESSRS. MERZ & McLELLAN.

Let HENLEY cables carry the current

An A.E.I. Company

By Appointment to Her Majesty The Queen Electric Cable Manufacturers

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Automatic pressure control

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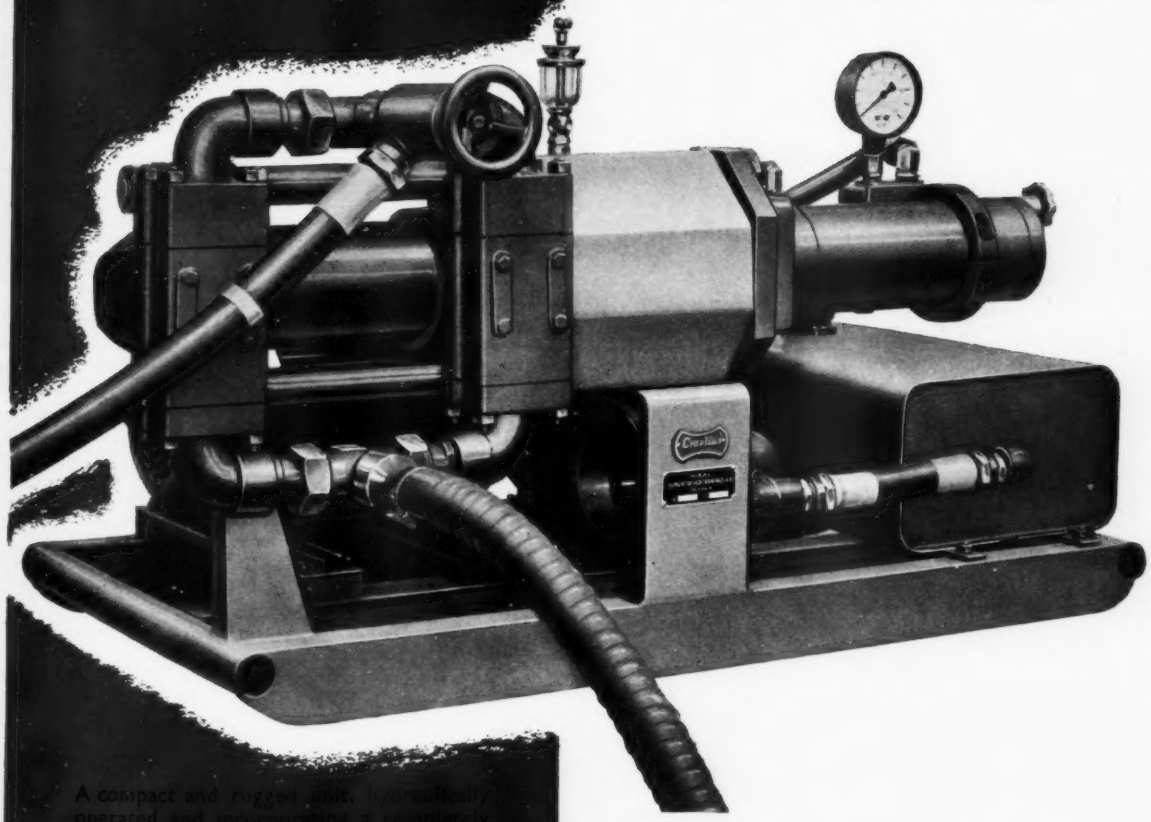
Grouting Pump



A compact and rugged unit, hydraulically operated and incorporating a completely dependable system of automatic pressure control whereby:-

(a) The grouting pressure can be varied and automatically controlled during operation.

(b) The grouting pressure can be limited to any pre-determined value in the operating range.

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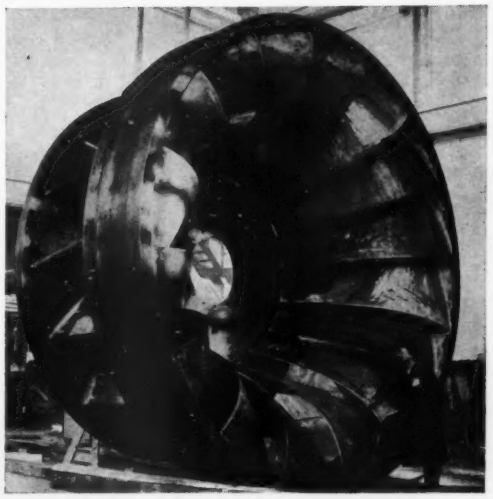

Above: *One of the runners for the Stornorrfors Power Station, Sweden. Each runner has a guaranteed maximum output of 200,000 HP under a net head of 75 m (246 ft.).*

Left: *A model runner of the Francis type to be tested in NOHAB's hydraulic laboratory.*

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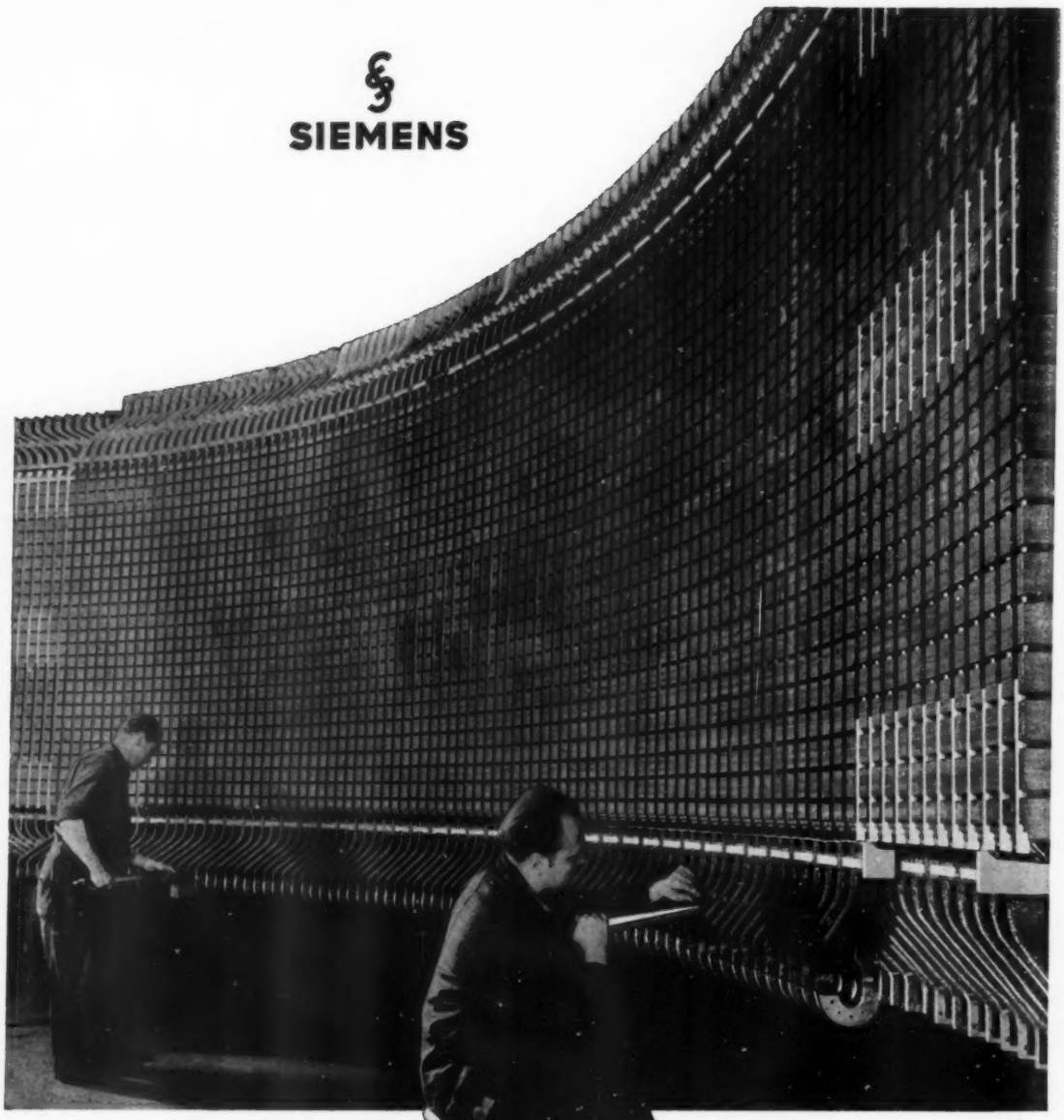

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Volume 11 Number 8

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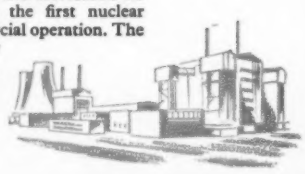

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WATER POWER

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Water Power from the Danube

LAST year, a special meeting of Government experts on energy problems stressed the need to harness the whole of the hydro-electric potential of the Danube in a rational manner. It was suggested that a detailed study of the subject should be entrusted to the Committee on Electric Power and the results of this enquiry have now been published.* The information given covers the installations already existing, definitely projected or in course of planning, and both the independent national schemes and joint plants situated on the common frontiers of the riparian countries are brought into the picture. In all, 44 schemes are envisaged, the combined annual output amounting to 31,000 GWh, of which 2,600 GWh, or 8·4%, has so far been developed. The schemes considered lie between the source of the river in Federal Germany and the Iron Gates section, about 1,850 km. downstream, where the Danube forms part of the common frontier with Romania, Yugoslavia and Bulgaria. Within this stretch, 600 km. lie entirely with in Federal Germany, 320 km. in Austria, 22·4 km. in Czechoslovakia, 350 km. in Yugoslavia and about 250 km. in Hungary. In certain intermediate reaches the river also forms a frontier between various countries, viz., Austria and Federal Germany, Austria and Czechoslovakia; Czechoslovakia and Hungary, and Romania and Yugoslavia.

At the present time eight hydro-electric plants are in commission on the Danube and are confined to the section in Austria and Federal Germany. Of these, five have a relatively small capacity (1·2 to 7·8 MW) and date from 1906 up to 1926. The Kachlet plant is also of long standing but has a capacity as large as 42 MW; it is situated near the frontier with Austria and lies 350 km. from the last upstream plant. The Jochenstein plant, which was completed in 1956, is situated at the point where the Danube crosses the frontier between Austria and Federal Germany. This plant formed the subject of an article contributed to this journal by Dr. E. Königshofer in the March 1957 issue. It will be recalled that five 28 MW sets are installed, making a total capacity of 140 MW, the annual output being 950 million kWh per annum. Both the constructional cost of the plant and its output are shared equally between the two countries concerned. Another plant, that of Ybbs-Persenbeug, is entirely in Austrian territory and was described in the June 1956 issue of WATER POWER by the same author. It is the largest of the plants covered by the enquiry and produces a total of 1,274 million kWh per annum from six sets having an aggregate capacity of 189 MW.

Apart from these two schemes and the relatively small installations higher up the Danube no further plants are actually in course of construction on the Danube. A number are being planned, however. Two of these, essentially Austrian, are expected to be started soon. The first of these, at Aschach, about 40 km. downstream from Jochenstein, will have a maximum capacity of 222 MW and is estimated to have an annual capacity of 1,400 GWh per annum. A further scheme in Austria, at Korneuburg-Klosterneuburg, is expected to be begun during the present year. This project will have an installed capacity of 180 MW and an estimated output of 1,206 GWh.

The Wolfsthahl scheme will be shared equally between Austria and Czechoslovakia and both countries will share in the cost of construction. The river bed will require to be excavated over a length of 10 km. and a head of 10 m. will thus be created. Six Kaplan turbines will be provided, each having an intake capacity of 440 cu.m. per sec. and giving an aggregate output of 1,400 million kWh per annum.

Other projected schemes may be conveniently divided into two groups, but no separate data are available. One group will consist of nine stations between Ulm and Donauwörth and a further 10 between Donauwörth and Kehlheim—all being situated in the upper reaches of the Danube within

*"Development of Hydro Power Stations on the Danube—Existing, under Construction or Projected." Sales No.: 59.II.E/Min.20. Obtainable from the Sales Section, European Office of the United Nations, Geneva, Switzerland, at 0.5 Swiss francs or from any sales agents for U.N. Publications in local currencies.

Federal Germany. The aggregate annual output from both groups is estimated to be 1,330 GWh, the installed generating capacity of the first group being 123 MW and of the second 106 MW.

The next group of projects falls entirely within Austrian territory, and in conjunction with the Ybbs-Persenbeug, Jochenstein and the other three plants to which reference has already been made, would result in the complete harnessing of the Danube between Passau and Wolfsthahl. These would have a total installed capacity of about 1,310 MW and produce some 8,639 GWh per annum.

Other schemes remaining are all joint affairs and have not yet got beyond the initial planning stage. Two projects will be constructed jointly by Czechoslovakia and Hungary in the section of the river which forms the common frontier between the two countries.

Joint projects are also being planned by Romania and Yugoslavia on the section of the river which forms a common frontier between the two countries and particular attention is being given to the site at the Iron Gates. Various designs are being considered but as yet none of them has been finally approved. Information from Yugoslavia envisages two schemes —those of Sip and Grouya. The summer and winter outputs of these two schemes would be wonderfully balanced; at Sip these outputs would be respectively 4,850 GWh and 4,350 GWh. At Grouya the summer and winter outputs would be 1,100 and 1,020 million kWh for each six-month period. Other projects are being studied but as yet these studies are far from approaching definite plans.

Certain of these power schemes—notably Kachlet and Jochenstein, near the Austria-German frontier, have been designed with an eye to improving the navigation, flood control and flow regulation. Both power stations are equipped with double locks are able to take at one time a tug and four double-coupled barges. Other new plants will be similarly designed to facilitate transport, and the backwaters will be designed to provide for irrigation.

British Columbia's Power Prospects

IN the course of his address to the 31st annual meeting of the British Columbia Power Corporation, Limited, the president, Mr. A. E. Grauer, surveyed the future power requirements and resources of the Province. Based on an annual growth of 10%, British Columbia will require 1,500 MW capacity by 1960, 3,750 MW by 1970, and 10,000 MW by 1980, without taking into account possible special loads such as aluminium or uranium processing.

Turning to hydro-electric resources, the Fraser River had to be ruled out at the moment because of the salmon problem, although it had the largest potential, which ranged from 6,000 to 10,500 MW, depending on whether the Columbia floodwaters were diverted into the Fraser or not. It also offered the cheapest power for the Lower Mainland and Vancouver Island. The release by the International Joint Commission of the results of engineering studies of the Columbia River showed that the Columbia in Canada offered about 4,500 MW including 50% of downstream benefits. The Peace River could provide about 3,000 MW near Hudson Hope, and the Homathko had a potentiality of about 800 MW. Thus there was an available capacity of more than 8,000 MW in the three available big rivers. Allowing for the 1,000 MW or more now under construction, the full capacity of these rivers would be needed by 1980.

Water Power in Ireland

THE Thirty-Second Annual Report of the Electricity Supply Board of Ireland for the year ended March 31, 1959, emphasises how weather conditions can affect output. The heavy rainfall during the summer and autumn of 1958 increased the output from the hydro-generating stations to a significant degree but the following dry period created difficulties as it took place at a time when the supplies of peat for certain thermal stations were below expectations. The output of the hydro-power stations was 773 million kW, or 12% above average. Of the total sources of supply—including oil, peat and coal—water power provided 42·7%.

The only new hydro station to come into operation during the year was the River Clady scheme in Co. Donegal. Here the civil-engineering works, including the Cung dam, the weir at Gweedore, the supply canal and the power station, are now virtually complete and the 4,000 kW set went into commission on February 19 of the present year. Much attention is being given to rural electrification and 2,700 miles of rural transmission lines were erected during the year covered by the report.

The report includes an account of the Board's activities in minimising the effects on the fish life of rivers subjected to hydro-electric development. On the Shannon, the Board is at present engaged on a programme to rehabilitate the stocks of game fish and aims at extending the catchment area open to salmon. As part of this scheme, a fish pass at Ardnacrusha was completed during the year. It is of the hydraulic fish-lift type and incorporates a number of new principles. The water supply is provided through a bypass and is delivered to the bottom of the tower instead of coming down inside the tower as in the normal Borland pass. A top horizontal channel provides a collecting ground for the descending smolts and kelts, and also allows the ascending salmon to rest before entering the headrace canal. A salmon hatchery having an initial capacity of 2 million eggs has also been built at Parteen Villa and steps are being taken to reduce predators and restock Lough Derg with yearling brown trout.

Turbines for U.S. Installation

DOMINION Engineering Company Limited of Montreal, Canada, has been awarded a contract to supply 10 Kaplan turbines to be installed in the Wanapum development on the Columbia River in the State of Washington, U.S.A. Each of the turbines will have a rated capacity of 120,000 h.p. when operating under an 80 ft. head at a speed of 85·7 r.p.m. The turbines will be among the largest Kaplan type units in the world.

The Wanapum development, owned and operated by the Public Utility District No. 2 of Grant County, Ephrata, Washington, is 415 miles above the mouth of the Columbia River. The capacity of the project will be 1,920,000 h.p., this including the 10 generating units at present planned and other six units to be installed later; this capacity will be integrated with

the Northwest Power Pool. The Harza Engineering Company of Chicago, Illinois, are the Consulting Engineers for this project which is to be constructed by Grant County Constructors, a joint venture of the Morrison Knudsen Company, Henry J. Kaiser Company, Macco, Raymond International and the F & S Construction Company.

In Canada, 46% of the installed hydro-electric capacity has been manufactured by the Dominion Engineering Company Limited, who also have turbines installed in Brazil, Russia, Ceylon, Pakistan and New Zealand; additional orders are at present being executed for New Zealand and India.

Mexican Electrification in 1958

NACIONAL FINANCIERA, S.A., reports that during 1958 Mexico's electrical capacity reached 2,506,253 kW, an increase of 12·8% over the 1957 figure. Last year 2,623 power plants of all types were in operation. Hydro-electric plants made up 45·3% of installed capacity. The most important in the thermo-electric group were the steam-operated plants, which accounted for 42·3% of total capacity. Diesel plants, with a combined capacity of 265,644 kW, and internal-combustion plants, with 50,151 kW, represented, respectively, 10·4% and 2% of total capacity. A large proportion (78·2%) of the combined power facilities supplied electricity for general public service.

Approximately 50% of the country's present electric power capacity is located in four Mexican states: the State of Mexico, where power plants account for a total of 537,567 kW, or 21% of the total for the Republic; Puebla, with 388,033 kW; Veracruz, with 233,083 kW; and Michoacan, 177,284 kW.

Guadalupe Power Loan in Colombia

THE World Bank has made a loan equivalent to $12 million for a hydro-electric power project which will provide 96 MW of additional generating capacity for Medellin and neighbouring towns in west central Colombia. The Grace National Bank of New York is participating in the loan, without the World Bank's guarantee, to the extent of $100,000, representing part of the first maturity which falls due February 15, 1963.

The loan has been made to the Empresas Publicas de Medellin, an autonomous public agency which provides power, telephone, water and sewage services in the Medellin area. The present capacity of the Empresas' power system is 136·5 MW in four hydro-electric power plants, two of which are on the Guadalupe river. Market studies show that the peak load will more than double by 1964 and triple by 1968. The Empresas are therefore undertaking the installation of 246 MW in hydro-electric plants on the Guadalupe and Nare rivers by 1964.

The project which the Bank loan will help to finance is the first phase of this programme. It consists of works to divert the Concepcion and Tenche rivers into the Guadalupe to increase its flow; the Troneras earthfill dam on the Guadalupe to create a reservoir with a useful storage capacity of about 32 million cu. m.; a power plant at the foot of the Troneras dam to be equipped with a 16 MW generator; and a second power plant to be known as Guadalupe III, equipped with two 40 MW generators. Also included in the project are transmission lines to connect the new plants with existing ones and with the city of Medellin, and extension of the distribution system in Medellin. Funds from the Bank loan will also be used to finance preliminary engineering studies for the power projects to be built on the Nare river as the second phase of the expansion programme.

The Guadalupe III power plant is scheduled for operation by mid-1961 and the entire project should be completed in 1962. The total cost is the equivalent of $19,350,000.

Sweden's Generating Capacity

ACCORDING to Mr. Olle Gimstedt, managing director of the Swedish Water Power Association, the harnessed water power in Sweden totalled 6,219 MW at the end of 1958, an increase of 717 MW over the year. The productive capacity at normal water supply rose by 3,400 GWh to 31,000 GWh per annum. Water-power plants at present under construction will add a further 2,000 MW to the existing rating, about half of these projects being accounted for by the State Power Board and the remainder by private and municipal companies.

The installed rating of thermal power rose by about 130 MW to some 1,600 MW in 1958. Plants for a total of 520 MW are under construction, and some 370 MW of this construction will be added this year.

The power industry's investments amounted to about Kr. 1,000,000,000 ($200,000,000) in 1958. Of this total close on 60% was accounted for by private and municipal companies. The power investments amount to 6% of the country's overall gross investments and to 30% of those of industry.

Speaking of Sweden's future power supply, Mr. Gimstedt said that there was no ready answer to the question of how much should be harnessed of Sweden's total exploitable resources of some 80,000 GWh per annum as too little is known about the future cost of nuclear power. Since Sweden will have no atomic power station in operation until 1965 and nuclear power cannot be utilised on a major scale until the 1970s, water power supplemented by steam-generated power will have to provide the solution until then.

Snowy Mountains T.1 Station Operating

THE T.1 underground power station on the Snowy Mountains project in South Australia began operation on May 4, when the first generator, with a capacity of 80 MW, was brought into operation. A few days later it was followed by a second generator bringing the station's capacity to 160 MW. This power is being fed into the New South Wales electricity system and later also into the Victoria system.

The water that operates these two turbines is stored in Tumut Pond dam on the Tumut river. It passes through a pressure tunnel and drops nearly 1,000 ft. through steel-lined pressure shafts to the turbines. The power station is 1,200 ft. below the surface and is 305 ft. long, 105 ft. high, and 59 ft. wide. The civil-engineering work for the power station was carried out by a group of French contractors, consisting of Compagnie Industrielle de Travaux, Société Général d'Enterprises, Etudes et Enterprises, l'Enterprise Industrielle, and Société Nationale de Travaux Publiques. Tumut Pond dam and the headrace tunnel

were constructed by an American joint venture—Kaiser-Walsh-Perini-Raymond. The installation of the generating plant, consisting of English Electric turbines coupled to ASEA generators, was carried out by the forces of the Authority.

The second two generators providing a further 160 MW will commence operation before the snow-melt period of the spring of this year. In four or five months' time the 14-mile Eucumbene-Tumut diversion tunnel will be in service, enabling a connection to be made to Lake Eucumbene. From this time onwards an additional 300,000 acre-ft. of water annually can be made available to the Murrumbidgee irrigation area—the first water of the scheme to be diverted from the eastward flowing rivers. In 1961, additional water and electricity will become available following the completion of the Tooma-Tumut diversion and the Murrumbidgee-Eucumbene diversion.

Careers in Civil Engineering

THE Institution of Civil Engineers, the Federation of Civil Engineering Contractors and the Association of Consulting Engineers are issuing a pamphlet entitled "Civil Engineering: Careers as Wide as the World." This is on offer at an exhibition being sponsored by the National Union of Teachers with the aim of showing boys of school-leaving age the many careers that are open to them if they take up a civil engineer's life. Models and dioramas of civil-engineering projects are on show and the diagrams and captions enable a boy to visualise the part he might play in creating a supremely important asset in almost any part of the world.

While considerable emphasis is placed on civil engineering, careers of other personnel, such as mechanical and electrical engineers, draughtsmen and office staff, have been by no means overlooked and are referred to specifically in the pamphlet.

Calgary Power Progress

AT the annual meeting of shareholders of Calgary Power Limited, the president, Mr. G. A. Gaherty, outlined the company's progress and future plans in power development. The addition of a 72 MW set to the Wabamun steam plant during the year brought the total capacity of the system—thermal and hydro—to 384 MW, which is four times that in 1948. The Spray-Rundle hydro-plant expansion programme was resumed in March 1959 and construction is going forward according to schedule. A further 80 MW of peaking capacity costing $6,500,000 will be added to these plants. This new capacity is scheduled for initial operation in October of 1960. This will bring the company's hydro-plant capability up to 320 MW.

Extensive surveys of possible water-power sites are continuing, but so far, because of the long transmission distances involved, none have been found that could provide base-load energy at as low a cost as will now be possible at the Wabamun steam plant. Several hydro sites are available on the Bow River that would be well suited for carrying the peaking portion of the company's load. Other considerations, however, make it preferable to develop, ahead of these, a site on the Brazeau River, 90 miles south-west of Edmonton. The development of this site will be a large and costly undertaking, but once the main dam and related development have been completed, additional generating units could be provided for peaking capacity as needed at a relatively low cost per kilowatt. It is estimated that the initial development of this site would consist of a main dam 1¾ miles long, 240 ft. high and containing some 10 million cu. yd. of earthfill, and a canal dike 12 miles long. Power would be generated from a 397 ft. head of water and the installation is tentatively planned for three 135 MW units.

The use of larger and more efficient generating units, the addition of machines to existing hydro stations, the application of automatic controls and careful planning of its operations has to date enabled the company to keep the price of power low as compared with other commodities. This is borne out by the average cost of service to the company's customers which stood at 1·47 cents per kWh in 1940 and 1·38 cents in 1958.

Malayan Water Power Scheme

A £100,000 contract has been secured by The Cementation Co. Ltd.—mining, civil and specialist engineers—in connection with the Cameron Highlands hydro-electric project in Northern Malaya.

The contract is for pressure grouting of tunnels and dam foundations; it is scheduled for completion in 1963 and has been awarded to the company by Hochtief AG—Philipp Holzmann AG, the German group acting as main contractors.

Portuguese Electricity Production

AFTER the unwonted recession in total output of 1957 due to the unusually dry year, the electricity production figures for Portugal for 1958 show a welcome resumption of the upward trend that has been so remarkable a feature since 1950. Indeed, when the results are expressed graphically the 1958 figures lie on the path of the curve for the past eight years, whereas those for 1957 are seen to be in the nature of a freak produced by abnormal conditions.

As compared with 1957, total production increased by 22·95% from 2,169 to 2,667 GWh, the increase in hydro-electric output being no less than 36·27%, from 1,841 to 2,508 GWh. Thermal production fell by 51·8% from 328 to 158 GWh; in the public-supply sector the reduction was from 227 to 51 GWh—no less than 77·43%.

Installed hydro-electric capacity increased from 977 to 1,146 MW, mainly as the result of the inauguration of Picote station.

Water Power Extension in New Zealand

WORK has started on a duplication of the existing power house at Maraetai, on the Waikato River, North Island. This will double the capacity of the station to 360,000 kW. Excavation for the second power house, of 180,000 kW, on the left bank of the Waikato downstream from the existing station, is under way and the provision of access roads has begun.

A start has also been made on an open cut which will take water from the existing lake to an intake dam 50 ft. high perched above the power house.

The project will involve the excavation of about 1·25 million yards of rock, apart from the excavation

involved for roads and the construction of cableways. It is due for completion by June 1, 1963, with the production of 72,000 kW from two of the five generators at that stage.

Swedish Developments

Bjurfors Kraft AB, Stockholm, have ordered three KMW Kaplan turbines for their new station, Bjurfors Övre, situated on the Ume River in the North of Sweden. Each turbine will have a maximum output of 23,700 h.p. at a head of 13·5 m. (44 ft.) and a speed of 107 r.p.m. They will be of conventional Kaplan type.

It will be recalled that in 1956 KMW received an order from the same company for three Kaplan turbines for their station at Bjurfors Nedre, 10 km. (6¼ miles) downstream of Bjurfors Övre. These turbines are each rated at 33,850 h.p. at 19·5 m. (64 ft.) head and a speed of 125 r.p.m. The first unit at Bjurfors Nedre is scheduled to be in operation by September 1959, the other two will be started at intervals of three months.

Peace River Power Development

LORD POLWARTH has been appointed a Director of Peace River Power Development Co. Ltd. to fill a vacancy caused by the retirement of Field Marshal Lord Alexander of Tunis owing to ill-health. Lord Polwarth, who is a Chartered Accountant, has many business interests and is Chairman of The Executive Committee of the Scottish Council (Development and Industry). Peace River Power Development Co. Ltd. was formed in British Columbia towards the end of last year to promote the development for hydro-electric purposes of the great water resources of the Peace River. A number of important British and Canadian Companies are interested in the Company, the Chairman being Sir Andrew MacTaggart.

Brazilian Traction Progress

ACCORDING to the 1958 Annual Report of Brazilian Traction, Light & Power Co. Ltd., sales of power in the Rio de Janeiro and São Paulo systems totalled 7,813 million kWh for the year, an increase of 12·4% over 1957. Major additions to generating facilities are now under construction to meet foreseeable load growth over the next few years and corresponding extensions of the distribution system will be required. Funds must be raised to meet a large portion of these capital costs, and negotiations to that end are proceeding with the International Bank for another dollar loan and in Brazil with the National Economic Development Bank and private financial organisations for cruzeiro funds. Arrangements have also been made to purchase a large amount of imported equipment from suppliers on extended payment terms. Meanwhile, Government activity in the field of electric power is increasing. A Federal tax is now being collected on sales of electric energy and paid into a Federal Electrification Fund for the purpose of financing the production, transmission, and distribution of electric power throughout the country, as well as for the development of the electrical equipment industry.

Reference is also made in the Report to the Furnas development on the Rio Grande, which was described in our November 1958 issue. This project, in which Brazilian Traction's subsidiary, São Paulo Light, is a major participant, is a joint venture of Government and private interests and will be financed, in part, with resources from the Federal Electrification Fund. The International Bank in 1958 made a long-term loan of $73 million to the Furnas Company. The site has an eventual capacity of 1,100,000 kW and it is expected that a substantial portion of the initial output will be available to São Paulo Light in the early 1960s.

On the Rio system construction is proceeding on the 93,500 kW Ponte Coberta plant, which will use the tailwaters from the Fontes and Nilo Peçanha plants.

Investigation on Earth Dams

MR. N. W. COLLINS, the senior designing engineer of the Ministry of Works, New Zealand, will visit Canada and the United States for about three months to study earth dam design and construction. The information he obtains is expected to be a big help in the use of earth dams in the development of New Zealand's hydroelectric power.

Expenditure on earth dams in New Zealand in the next five years will be more than £2 million a year, and big savings are hoped to be made by bringing New Zealand methods up to date.

For example, if a change could be made in the specification for the new 480,000 kW Benmore dam on the Waitaki river (South Island), even a saving of only 6d. a cu. yd. in the average cost of handling the material, would result in a saving of nearly £500,000. An earth dam could well be a highly economic proposition on the Wanganui river where a 700,000 kW station is envisaged.

Correspondence

Electrification in Turkey

To the Editor, WATER POWER

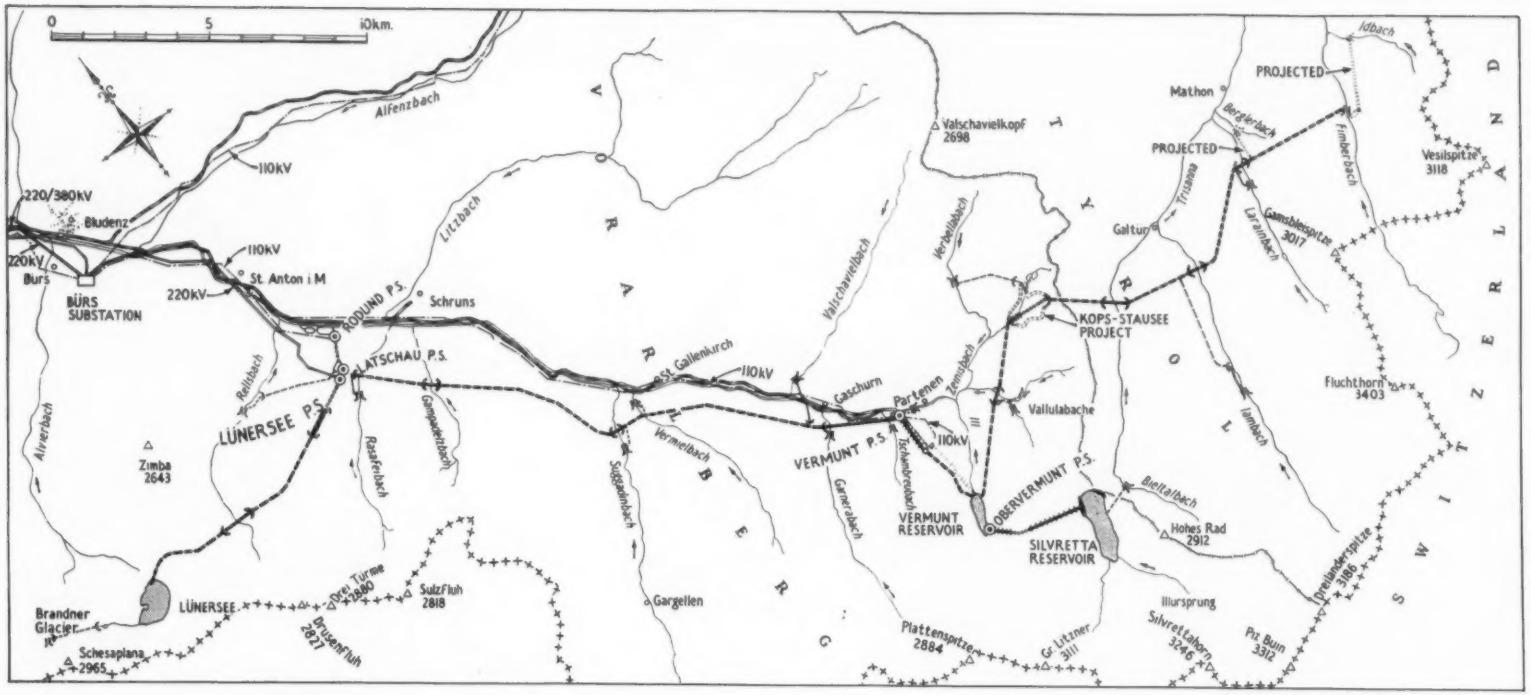
I was surprised to read the abstract under the heading of "Electrification in Turkey" which appeared on page 239 in your June 1959 issue. This abstract briefly states that the 1,000 MW Keban scheme and 600 MW Rezuk plant are now under construction.

I wish to correct certain points in this abstract which are misleading. From the preliminary studies, already completed, the above-mentioned projects are technically and economically sound as far as the dam and the power station are concerned. However, transmission lines from these hydro plants involve a very serious problem because of the transmission distance, nearly 1,000 km.

I should like further to add that a network analyser study has been carried out at B.T.H. Works for this purpose in 1958.

At present the investigations are still going on and no construction work of any kind has yet started.

T. FIKRET SUER,
Chairman World Power
Conference Turkish National Committee



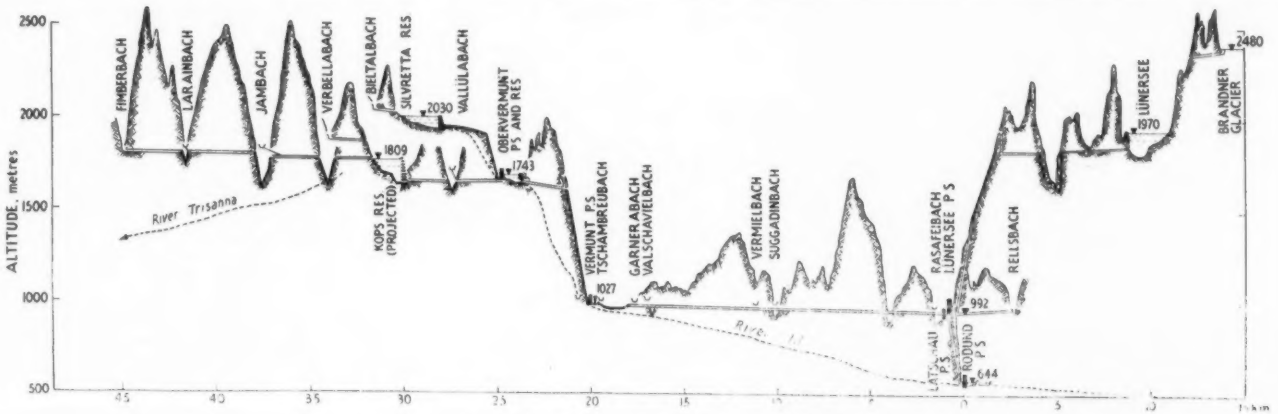


Fig. 1. Map and profile diagram of the Vorarlberger Illwerke system

Fig. 2. Silvretta reservoir and dam

Large-Scale Pumped Storage

The Vorarlberger Illwerke system in western Austria has been designed primarily to supply peak-load power to the Central European grid. At Lünersee the organisation possesses what is believed to be the largest pumped-storage station in the world yet in operation

PART ONE

THE hydro-electric system owned by the Vorarlberger Illwerke A.G., in western Austria, which we were recently privileged to visit, is not only interesting in itself but is important in that it exemplifies certain major trends of thought as to the function of water power in power economics. The system exists primarily to provide peak-load power to the Central European Grid, especially to the South German and Rhine and Ruhr area, where the base load is carried mainly by steam power stations fired with brown coal. To assist in meeting the peaks a pumped-storage stage was introduced in 1954, and recently a pumped-storage station has been put into service based on the use of the lake Lünersee as a storage reservoir, which, it is believed, will remain the largest plant of this type in the world until the Ffestiniog scheme in North Wales has been completed. During off-load periods the Illwerke pumps are driven by power from the thermal stations in the network.

Thus the Illwerke system constitutes an important example of the international exchange of power—a movement in which Austria has always been in the forefront—it is an admirable instance of the correlation of thermal and hydraulic power in such a manner that each form of prime mover is able to operate under the conditions for which it is best suited, and it is a practical demonstration of the increasing interest that is now being taken in the development of pumped storage to increase peak-load capacity.

The first stage of the scheme—the Vermunt stage—commenced operation in 1931, and ultimately the development will cover the entire catchment of the river Ill, a tributary of the Rhine, in the Province of Vorarlberg. A map and profile diagram of the present state of development are given in Fig. 1.

The head storage of the system is provided by Silvretta reservoir, which impounds 38·6 million cu. m. at a level of 2,030 m. and supplies the 30 MW Obervermunt station. This station discharges to Vermunt reservoir, which has a capacity of 5 million cu.

Fig. 1. Map and profile diagram of the Vorarlberger Illwerke system

Fig. 3. Lünersee dam under construction, with the new Douglashütte in the background

m. at a level of 1,743 m. and also receives the diverted headwaters of a series of Tyrolean mountain streams. From this reservoir the water descends to Vermunt power station, of 141 MW capacity, discharging to a 110,000 cu. m. tailpond at a level of 1,027 m.

Thence a free-flow tunnel, 18·74 km. long, leads to a daily-storage reservoir at Latschau, holding 970,000 cu. m. at a level of 992 m., and to utilise the head between the tunnel outlet and the reservoir an 8 MW station has been built on the reservoir.

On the bank of the Latschau reservoir is located the new Lünersee pumped-storage station, working in conjunction with a natural lake, the Lünersee, which has been impounded to retain 76 million cu. m. at a level of 1,970 m. At present the station contains five pump-turbine-alternator/motor sets having an aggregate installed capacity of 224 MW for power production and 252 MW for pumping, but space is available for a sixth set, which will raise these figures to 269 MW and 302 MW respectively.

From Latschau reservoir the water descends to Rodund station, which has a generating capacity of 173 MW. One of the machines in this station can also drive a 40 MW pump to return water from the tail-pond, at a level of 644 m., to Latschau reservoir. A second machine is also arranged so that it can drive a future 40 MW pump.

At present Rodund power station constitutes the final stage of the development, but six further stages downstream of Rodund are contemplated for future

TABLE I.—PLANT CAPACITIES, ETC., OF THE UPPER-ILL/LUNERSEE SYSTEM

Power plant	Average net head	Flow		Net storage	Stored energy (above Rodund tailpond)	Annual capacity		Annual production	Energy absorbed in pumping
		Turbines	Pumps			Turbines	Pumps		
	m.	cu. m./sec.	cu. m./sec.	mill. cu. m.	GWh	MW	MW	GWh	GWh
Obervermunt	257	14	—	38·6	111·5	29	—	45	—
Vermunt ...	665	26	—	5·0	12·1	140	—	424	—
Latschau ...	11–28	40	—	0·1	0·1	8	—	23	—
Rodund ...	328	60	20	1·0	0·7	170	80	486	64
Lünersee ...	848	31·5	26·5	76·0	209·0	217	253	353	536
Total					333·4	564	333	1331	600

Notes: (a) These figures include the sixth machine at Lünersee and the second pump at Rodund, but do not include the future Id, Bergler and Kops diversion.

(b) All capacity and energy figures are net average annual values as measured at Bürs substation.

construction as the load requires.

The German organisations to which peak-load power is supplied are Rheinisch-Westfälisches Elektrizitätswerk A.G., Essen, and Energie-Versorgung Schwaben A.G., Stuttgart-Biberach. Power is also supplied to two Austrian provincial supply authorities Land Vorarlberg and Land Tirol and to the Austrian Grid controlled by Österreichische Elektrizitätswirtschafts A.G. (Verbundgesellschaft).

Our main purpose in this article is to describe the Lünersee section of the development and to discuss the influence of pumped storage on the capacity and mode of operation of the system, but we will first fill in a few technical details of the other sections mentioned in the foregoing outline. Storage and plant capacities, production, and other relevant data will be found in Table I.

Fig. 4. Concrete-lined section of Lünersee pressure tunnel

Fig. 5. Part of the Lünersee penstock

Obervermunt Section

This, the uppermost section of the development, utilises a catchment area of 45 sq. km., of which 13 sq. km. is glaciated and 10 sq. km. is derived by diverting the headwaters of the Biel stream to Silvretta reservoir. This reservoir, with a capacity of 38·6 million cu. m., is formed by a main gravity dam containing 407,000 cu. m. of concrete, 80 m. high above lowest foundation, 432 m. long at crest and 52 m. maximum width, a lateral dam of similar type, 31 m. high, 140 m. long and having a volume of 18,400 cu. m., and a gravel dam with reinforced-concrete core, 25 m. in maximum height, 733 m. long at crest, and 121 m. maximum width. The Biel stream diversion in this storage basin is effected by a tunnel about 1½ km. long. A view of Silvretta reservoir and main dam is given in Fig. 2. The works were completed in 1948 and the first maximum storage took place in 1950.

From the main dam a pipeline 3,270 m. long and ranging from 2·4 to 2·1 m. in internal diameter is carried above ground to Obervermunt power station, where two 15 MW vertical Francis sets are installed. Since there is no surge shaft, these machines have been provided with relief valves and with governing which permits a substantial rise in speed in the event of load shedding. This station is remote controlled from Vermunt. It has been in operation since 1943.

Vermunt Section

Vermunt reservoir, with a capacity of five million cu. m., is formed by a concrete gravity dam having a volume of 144,000 cu. m., 50 m. high above lowest foundation, and 386 m. long at crest on the main dam and 102 m. long on the lateral dam. Besides receiving the discharge from Obervermunt station, this reservoir receives 161 million cu. m. per annum from diversions from three mountain streams in Vorarlberg and three in Tyrol. In connection with these diversions a reservoir of 44 million cu. m. capacity is projected in the Kops valley, and the diversion of a further stream in the Tyrol is planned.

From Vermunt reservoir a pressure tunnel 2·5 km. long and 2·8 m. in diameter conveys the water to two penstocks, each 1,368 m. long and 1·77 to 1·35 m. in diameter, leading to Vermunt station, situated at Partenen. This station commenced operation in 1931 with four horizontal single-nozzle Pelton sets, a fifth

Fig. 6. Waagner-Biro 490 h.p. winch for the lower section of the Lünersee penstock haulage

Fig. 7. View of lower haulage house from upper haulage track

Fig. 8. Car approaching the mountain terminus of the upper haulage

set being added in 1939 consisting of a two-nozzle 50,000 h.p. Pelton set coupled to a 39 MVA generator. In 1952 and 1953 the four single-nozzle turbines were replaced by two-nozzle machines of 25% greater power, and the capacity of each set is now 30 MVA.

An equalising basin of 110,000 cu. m. capacity has been constructed just below the station, and the discharge from Vermunt station is supplemented by a diversion from the Ill at this point.

Latschau Section

From the compensating basin at Partenen a headwater conduit leads to the daily-storage basin at Latschau which supplies Rodund station. This conduit is 18·74 km. long. It comprises 15·71 km. of free-flow tunnel, 0·45 km. of open and 0·47 km. of covered channel, 0·36 km. of valley crossings by three reinforced-concrete aqueducts, and 1·75 km. consisting of a reinforced-concrete syphon. Six side intakes have been constructed at various points along its length, and these, together with the Ill diversion at Partenen, increase the utilisable flow from 26 to 44 cu. m. per sec.

An independent diversion from the Rells stream is also fed into the Latschau reservoir through a 2·93 km. free-flow tunnel.

The Latschau storage basin, of 970,000 cu. m. capacity, was formed by moderate excavation and extensive banking to provide a maximum depth of 18 m., the bottom and banks being lined with concrete and bitumen sealing. A solid spillway and discharge tunnel lead to the Rodund plant, and as a further safeguard against an excessive rise in the water level a discharging device with an automatic valve is also installed. These precautions are necessary because the basin receives not only the flow from the headwater conduit but also the discharge from the Lünersee machines when running as power units and the storage water pumped up from Rodund.

Between the outlet of the headwater conduit and the surface of the water in the Latschau basin there is an available head ranging between 11 and 28 m. This is utilised in the Latschau power plant, which is housed in a reinforced-concrete "tower" built actually on the floor of the basin and containing two 5 MVA Kaplan sets. These machines are controlled from Rodund, and commenced operation in 1950.

Lünersee pumped-storage station, of course, is situated on the bank of the Latschau basin, but before describing it we will follow the main flow down to Rodund.

Rodund Station

From the Latschau reservoir a steel-lined pressure shaft 854 m. long and 3·2 to 3·05 m. in diameter descends to Rodund power station, where four 53 MVA generating sets are in operation. They are driven by Francis turbines, but are disposed horizontally to enable storage pumps to be coupled to two of the sets. One such pump has already been installed; it is a two-stage machine rated to deliver 10 cu. m. per sec. against a head of 348 m. and absorbs 40 MW. For starting, it is emptied by compressed air and run up to speed by a small direct-coupled Pelton turbine, after which it is connected to the electrical machine by a dog-clutch coupling. The electrical machine can also be run as a synchronous condenser, and the various operations of power generation, power factor correction, and pumping are controlled by pushbutton. A second generating set is arranged for the addition of a pump when required.

Two tailwater basins, one of 685,000 cu. m. to serve the pumps, and a second of 295,000 cu. m. capacity to regulate the discharge into the river, have been constructed adjacent to Rodund station, the machines of which have been set low enough to enable the pump to draw without difficulty.

The first two generating sets have been in operation since 1943 and the third since 1944; the fourth unit and the associated storage pump were commissioned in 1952.

Lünersee Lake and Dam

Lünersee lies in the Ratikon close to the Swiss border, and is the largest high-level natural lake in Austria. Its natural storage is 50 million cu. m. at a surface level of 1,943 m. but it would be possible to raise the level sufficiently to impound 94 million cu. m. gross storage. In the actual scheme it has been dammed to afford a live storage of 76 million cu. m. between a maximum retention level of 1,970 m. and a minimum level of 1,897 m.

Run-off from the Brandner glacier, amounting to 6·1 million cu. m. per annum, has been diverted to Lünersee through a free-flow tunnel 1·34 km. long. Including this diversion, the natural flow into Lünersee amounts to 17 million cu. m. per annum, so that the balance of 59 million cu. m. represents the capacity available for pumped storage.

Actually Lünersee was considered for use as a hydro-electric reservoir in the early 1920's, and the ridge of rock forming the lake was grouted in preparation for this use, but the scheme was later abandoned. This ridge has now been used to carry the dam, which is of the plain concrete gravity type, 28 m. high above lowest foundation, 380 m. long at crest, and containing 41,000 cu. m. of concrete. It is undulating in plan to follow the natural line of the ridge. Intermediate and bottom discharge tunnels are cut through the ridge, and an uncontrolled spillway has been cut in the rock towards the left bank, the channel passing through the dam. A submerged intake, protected by a grille, leads to an intake tunnel passing through the ridge to an underground valve chamber containing two 2·5 m. diameter J. M. Voith, St. Pölten butterfly valves controlling the flow to the supply tunnel. An intermediate discharge at the right-hand end of the dam leads to the supply tunnel at a point just beyond the valve chamber.

Raising the level of Lünersee involved the flooding of a mountain hostel on its shore—the Douglashütte—and a new Douglashütte has been built on the left-hand abutment of the dam.

Lünersee Supply Conduit

The supply conduit from Lünersee lake to the generating/pumping station at Latschau traverses a horizontal distance of 8¼ km. and is divided into several sections. The first of these, from Lünersee to the Salonien valley, is 3·06 km. long and consists of a circular pressure tunnel 3·5 m. in diameter, lined with concrete and also steel lined where necessary.

To cross the Salonien valley an inverted syphon 1·39 km. long has been constructed consisting of two

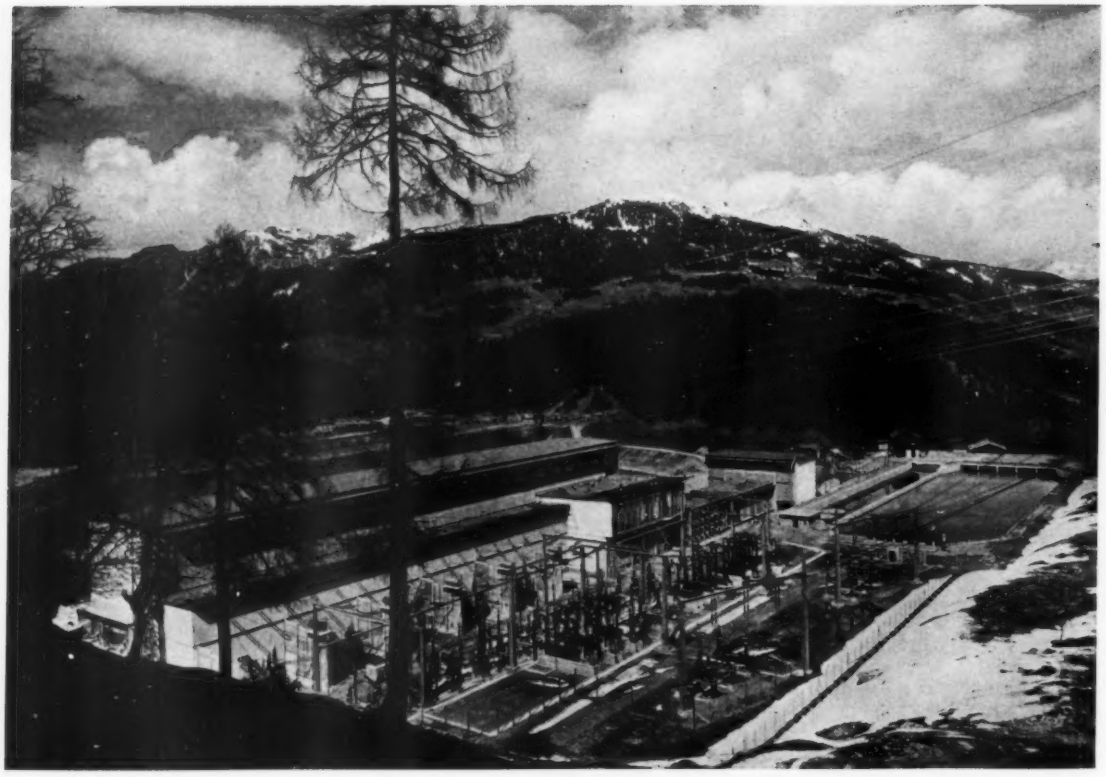


Fig. 9. General view of Lünersee station and pumping basin. The pumping basin will be seen on the extreme right and the switchyard in the foreground

inclined concrete-and-steel-lined pressure shafts, each 2·6 m. in diameter, decreasing to 2·4 m. at the deepest point.

From the downstream end of this syphon the pressure tunnel continues another 2·47 km. to the surge chamber at Grüneck, which is of the double-chamber type 128 m. high measured from the middle of the pressure shaft to the maximum static water level. The lower chamber has a capacity of 1,715 cu. m. and is connected by an inclined shaft, 38 sq. m. in section, to the upper chamber, which has a capacity of 1,590 cu. m. The maximum surge above static water level is 18 m. and the lowest negative surge is 28 m. below minimum water level.

From the surge chamber a pressure tunnel 3·2 m. in diameter and 0·5 km. long armoured with steel ranging from 15 to 19 mm. in thickness leads to the valve chamber, which contains a butterfly valve 2·5 m. in diameter.

Rock conditions did not favour the construction of a pressure shaft over the entire distance between the valve chamber at Grüneck and the station at Latschau, so a combined solution was decided upon. From the valve chamber to Matschwitz, about halfway down the route, a steel penstock has been laid, 1·02 km. long and 2·25 m. in diameter, but below Matschwitz the penstock gives place to a pressure shaft, 1·35 km. long and 2·15 to 2·05 m. in diameter, the thickness of armouring ranging from 26 to 65 mm.

To facilitate the erection of the penstock and for subsequent maintenance and access, a rope railway was built by Waagner-Biró A.G. extending from the side of the Latschau basin to the vicinity of the valve chamber. This railway is in two sections, the transfer station between stations being at Matschwitz where the exposed penstock enters the pressure shaft. The lower section is arranged as a single-track haulage having a single car and with the electric winch located at the transfer station. It handles a payload of 25 tons, which it raises a height of 523 m. in a horizontal distance of 1,190 m. and a track length of 1,312 m., the ruling gradient being 71% and the minimum gradient 16%. The track gauge is 1 m. The winch drum is 4·3 m. in diameter and is driven by two 245 h.p. motors through flexible couplings and a reduction gear which enables the rope speed to be set at 2·6 m. per sec. for loads up to 8 tons and for passenger riding, and to 1·3 m. per sec. for heavy loads.

The upper section is arranged as a balanced haulage with two cars connected by a common rope and running on a single track except at the midpoint, where an automatic passby is provided. This section raises a payload of 15 tons a vertical height of 362 m. in a horizontal distance of 1,165 m. and a track length of 1,224 m., the ruling gradient being 40% and the minimum gradient 23%. The arrangement of the winch is generally similar to that for the lower section, but in view of the lighter duty the twin motors are rated at 92 h.p. each.

A full complement of braking and safety gear is provided both on the winches and on the cars.

(To be continued)

Fig. 1. Moran dam site on the Fraser River, looking south

Moran Dam Today

The author, who for the past four years has acted as Consulting Engineer and Project Engineer for the Moran Power & Development Co. Ltd., reviews the present situation regarding this Fraser River project in British Columbia, with special reference to the salmon problem

By RUSSELL E. POTTER, P.Eng.

LATE in 1954 a group of men decided that they would make an application to the provincial government of British Columbia for the right to develop the Moran dam site on the Fraser River. A company was incorporated and work started on studies and designs. What they had set out to do was no mean undertaking.

The site is in the Fraser River Canyon. It has been known for years. Alexander Mackenzie, the first explorer to reach the Pacific north of Mexico, abandoned the river route after, hearing about the canyons ahead before he reached this section. This was in 1793. Simon Fraser probably rode his big canoe through this site in 1808, but paddle boats could not get nearer than Soda Creek, 130 miles away.

The dam would be one of the largest in the world. The cost would be in the region of £200 million and the energy developed would be four million horsepower with an ultimate possibility of six millions.

The canyon is narrow and the rock walls are suitable for an arch dam. This dam would raise the water level 750 ft. The Pacific Great Eastern Railroad passes along the side of the mountain directly above the site and parallels the full length of the reservoir. In spite of the lake, 172 miles long, which the dam would form, no towns, forests or mines would be flooded and very little agricultural land. The lake formed would average less than three-quarters of a mile wide but would have an area of some 65,000 acres. The studies showed that the single dam could produce a regulated flow of 40,000 cusecs, with a minimum head of 600 ft. The lake and river system upstream from the site makes storage of even the entire flow of the river possible, equivalent to an average flow of almost 60,000 cusecs. The development of this storage would be undertaken when the additional power was required.

The newly-formed company met Premier W. A. C. Bennett and asked for the right to apply for a licence

to develop the Moran site. Some years before this a reserve had been placed on the Fraser River to prevent power development licences without special action by the legislature. The government were not willing to lift the reserve but went so far as to place a reserve to the staking of mineral claims or timber claims in the area to be potentially flooded. Encouragement was given to the application but with the proviso, "Satisfy the fisheries' people then come back to see us." It was a difficult condition but not one that the company felt to be impossible, and work was continued on the design with the idea of developing the power and saving the fish.

The Moran site is 220 miles upstream from the mouth of the Fraser River. On the average the value of the sockeye salmon amounts to about £1 million at today's prices; all these are spawned above the site. The fishery interests believe the salmon industry can be increased far beyond this value. Power dams on other rivers have in many cases damaged fish runs and a dam 750 ft. high would seem to impose an impossible barrier to the spawning grounds.

From the very beginning talks were started with the Federal Department of Fisheries, the International Pacific Salmon Fisheries Commission, the Provincial Department of Fisheries and the Fish and Game Department. The object was to obtain as much information as possible about handling the fish and then to design to the criteria established. The first report from the Federal Department of Fisheries was promised in six months but so far no construction information has been received. The company have therefore proceeded with their design work and have also pushed their investigations with the assistance of the fisheries personnel and the engineers of the States of Washington and Oregon who have a realistic approach to the problem and feel that both the fishing and power resources of the river may be developed together.

The problem of taking the adult fish over the dam by mechanical means seems to be the most feasible. Fish ladders, miles in length and on steep canyon walls, are out of the question, but short ladders leading to large tanks mounted on cars moving up and down the face of the dam are quite practicable. The number of fish to be handled may be as many as 750,000 in a 24-hour period, according to an estimate made by the Fisheries Department in another study of the river. It is some ten times the maximum number of fish in the river today but indicates what they hope to achieve. Objections have been raised that the fish would be lost in the lake above, but it should be remembered that these same fish will normally travel through larger lakes before they reach their spawning grounds, and the 40,000 cusecs through Moran Lake will give much more current to guide them than in the lakes ahead. This objection, therefore, does not seem valid.

The problem of handling the fingerlings has always been a major one. These one-year old fish which make their migration to the sea with the spring flood have always been considered the most difficult to save. Going through the turbines would kill them, or even going over a dam could be fatal.

It has been established that on their migration the young fish keep mostly in the top 15 ft. of water; few are found below 30 ft. They follow the current and in an ordinary dam this means that they would pass into the turbines or go over the spillway.

At Moran, with a dam 750 ft. above the tailwater, the turbine inlets would be placed 100 ft. below the lowest drawdown. The regulating gates for passing the flood waters would also be at a similar depth. No small fish would get to such depths and the spring flood that brings them down would put the gates under an even greater depth of water, and no water

Fig. 2. Aerial view of Moran dam site

Fig. 3. Outline of Moran dam superimposed on site, looking north

would consequently pass over a spillway.

The problem then is to create a surface current to the face of the dam and allow enough water to pass through to attract the small fish. This can be done through gates placed in the face of the dam to the maximum drawdown level. The water may then be flumed or even sent over a fall into a deep tailrace pool, it having been determined that the small fish survive such a free fall safely. Both the lift method for the adults and the flume and fall method for the fingerlings are now being used successfully at various places in the States of Washington and Oregon.

Why then should not such a system be accepted for Moran and give British Columbia probably the largest block of cheap electric power left in North America? Moran is only 103 miles by air from salt water and 124 air miles from a population of one million energetic people with solid government, hard money and boundless resources. There are several reasons, but the fish problem, of course, comes first. The million pounds worth of fish caught annually at present may be greatly increased in the future. Even so however their value to the country could never compare with the annual thirty billion kWh of hydro-electric energy that could be supplied to all the primary and secondary industry it would foster. This has been computed to be anything up to £700 million per annum with total development.

By raising the Fraser to an elevation of 1,547 ft. it would be possible to irrigate some 190,000 additional acres of good agricultural land for which at present there is no alternative source of water. The additional weight of beef that might be raised by using this available acreage for producing feed could be far greater than the weight of salmon that might ever be produced above the site of the dam.

The salmon question is largely emotional and as such is difficult to handle. Although the electrical rates paid in the province today are 50% or more higher than comparable rates in other parts of Canada and the Pacific Northwest, British Columbians do not yet appreciate the fact that they are paying for their salmon on their electric light bills. It is something of a tragedy to the area that a million kilowatt steam plant using irreplaceable natural gas is now being built near Vancouver and this in a province where there is more than 30 million h.p. of water power awaiting development.

It is interesting to note also that of all the salmon in the Fraser River only the sockeye is affected to any extent by Moran. The pinks and chums which both occur in greater numbers do not migrate so far upstream and the springs and cohoes are likewise little affected. The main supply of sockeye too is from the Adam's River, a tributary of the Thompson Branch of the Fraser River. Here, every four years, as many sockeye are produced as in all other sections of the Fraser River system put together. This area would not be touched by Moran, which is some 70 miles upstream from Lytton where the Thompson flows into the Fraser River. If all of the fish were killed it is doubtful if they would represent more than 5–6% of the total salmon catch of British Columbia. Tremendous strides are being made in Washington and Oregon in solving the salmon problem. Fish culture, fish farming, transplanting of runs and numerous other developments are showing definite results.

Other reasons have affected the development of the Fraser River. Two of the great power rivers existing in the province are the Columbia and the Peace. The Columbia can be developed for some 3½ million

horsepower in British Columbia with a total useful storage of something approaching 20 million acre ft. This storage would reduce flood danger in the lower reaches in Washington and Oregon and would firm up power in the United States over some 1,250 ft. of fall, most of which will soon be developed. The question of how the downstream benefits should be divided between the two countries has held up this development, and the United States, who evidently want to get their own plants built, have not pressed for additional storage in the Upper Columbia. A scheme proposed in Canada to divert the Columbia River to the Fraser and develop it entirely in British Columbia appears to have shaken the Americans into realising that a tremendous asset in cheap hydro power could be lost to them for ever. The Columbia, like the Fraser, is a spring run-off river. Any storage that reduces the spring flow and increases the winter flow, such as Mica Creek would do, is like found power because at most of the American plants the necessary turbine capacity is in place and cannot all be used at low flows.

The Columbia at Mica Creek is about 272 air miles from Vancouver and tide water. It has no fish problem but transmission adds both cost and difficulty to its development. The share of the downstream power that would come back to Canada should reduce the total cost of the power to British Columbians by about one third. The Columbia River will probably have to be developed by the Provincial Government as the international aspect of downstream benefits almost precludes the possibility of private enterprise taking over.

The Peace River lies over half-way up the Province of British Columbia and is 475 miles in an air line from Vancouver. Here a dam of some 450 ft. in height might be built to develop the average flow of the river, estimated to be some 33,000 cusecs, justifying an installation of about two million horsepower. A second dam downstream could add to this power. Here again the problem of transmitting immense quantities of power over excessive distances and rough terrain limits the appeal of such a development.

The Fraser River is more conveniently situated and drains an area of 90,000 sq. miles. Its delta provides about half of the arable land developed in the province. This land is protected by a system of dykes which so far are valued at £13 million.

The 1948 flood devastated much of this land at a cost to the country of some £7 million. Moran dam alone would eliminate this flood danger. An alternative flood proposal has been proposed by the Fraser River Board that would cost as much as Moran, develop about one quarter the power, but be far enough up the river to escape the salmon problem. There would not be sufficient power developed to make the system self-supporting, and it would therefore have to be subsidised by the government.

Navigation improvement, silt control, and the tourist attraction of one of the world's largest dams, are other values that could be placed to the credit of the Moran development.

Nuclear power cannot be eliminated as a consideration. It is not foreseen that nuclear power costs will be competitive with steam for another 25 years. In that time the capital cost of Moran dam could be paid off. The whole question is one of cost. By building Moran dam British Columbia could have the greatest block of low-cost power in the world and this would help to compensate for its great distance from population centres and world markets, or it can develop the other rivers at progressively higher cost and lesser advantage to the province, or it can wait for nuclear power which everyone will have.

For those with the responsibility of government the problems are complex in the extreme.

The Swedish financier Wenner-Gren is at present investigating power development on the Peace River. The area to be flooded, which includes an immense forest, and the resources that must be given to the company to help make the project feasible, raise many questions in the public mind. The relative cost of power from the three sites has been computed by various people but generally falls as follows, all prices per kilowatt hour at tide water: Moran, three mills; Mica, six mills (or four if anticipated downstream benefits are obtained by Canada); Peace River, seven mills.

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New Zealand Annual Report

The Annual Report of the New Zealand Ministry of Works gives an interesting summary of the work accomplished, in hand, or projected for the year ended March 31, 1959. In regard to hydro-electric supply, the four existing generating units at Roxburgh are to be increased to eight and at the same time steps are being taken to provide extra storage for the plant by erecting a control dam on Lake Hawea. This dam, which is now nearing completion, will be capable of storing the flow of the Hunter river on an annual basis and enable eight units to be operated at Roxburgh on normal load factor.

Operations in connection with Benmore are progressing very favourably; the river diversion culverts have now been planned and it is estimated that the first power will be produced in 1965. This is the largest project yet to be attempted in New Zealand. A double-barrel arched concrete diversion culvert is virtually complete and the preliminary design for the 360 ft. high earth dam has been sufficiently finalised to enable the lower courses to be laid down.

Investigation into further hydro-electric projects is being actively pursued in both the North and South Islands. In the North Island the development of the Tongariro river is being investigated with the idea of diverting extra water into Taupo. Also an examination of the possibilities of the Wanganui river has been begun. In the South Island the potentialities of the Upper Waitaki are being investigated between Benmore and Lake Tekapo. As yet these investigations are far from being complete, but preliminary findings suggest that the water-power resources of the North Island in particular have been underrated. It is considered that the construction of further water-power stations will take preference over coal and atomic sources for many years to come.

Storage in Natural Lakes

A study of the development of natural lakes by underwater piercing or other means that avoid artificially raising the storage level. An extensive bibliography has been compiled

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HAD this paper been written a century ago when alternative headings were the vogue, its prosaic title might well have been replaced by "Storage in Natural Lakes, or Damn the Dam." Useful storage is that above the outlet of a basin. The customary way to obtain such storage is to construct the outlet, complete with gates and expensive means of protection against seepage along the sides and bottom of the passageway, and then build a dam. A much less frequently employed procedure is to pierce a hole connecting a deep point in a natural lake to some lower point on the ground surface some distance away. This hole, too, requires gates and possibly lining, but the dam, watertight and stable, exists automatically as soon as the hole is punched through.

Advantages of Natural Lakes for Storage

In a rugged mountainous region deep lakes may exist quite close to abrupt slopes. Here, where the problems of transport are most onerous, where natural dam materials of the proper quality may be non-existent, and where bitter winters play havoc with construction through frost damage and through curtailment of working time, a method of obtaining storage which requires only a relatively small tunnelling crew, able to work under shelter the year around, may show marked economy not only in the cost of labour and materials, but, often more important, in the substantial advancement of the completion date of a project.

For a storage reservoir to function effectively large variations in depth are essential. With the traditional development by damming, serious problems in land acquisition and route relocation often arise. If, on the contrary, the normal level is to become a maximum rather a minimum, expense and litigation may be avoided. In a few cases the removal of the flood threat has been a benefit of piercing ranking in importance with power development.

A dam requires a spillway; for a natural lake some adequate overflow facility will have come into existence over geological time. Thus, this item of expense may be eliminated. In many cases, however, the natural spillway has actually become the emplacement of a secondary overflow dam and the lake as finally developed owes part of its storage volume to the depth of piercing below natural level and the rest to the depth retained by a dam above this level.

Storage volume behind river dams has often been filled by silt. The continued existence of a natural lake, with the possible exception of a few formed in historical times by landslides blocking rivers, is in itself evidence that the silt inflow must be moderate; had it not been, the lake would have been replaced by a swamp years ago. A lake, moreover, is never pierced at its maximum depth, whereas a valley dam is almost inevitably contiguous to the deepest point in its reservoir, and, after a few years of silting if not immediately, the deepest spot remaining is at the outlet. Evidently then, water quality tends to be better from a natural lake than from one created by a dam.

Preliminary Studies

It is axiomatic that a competent geologist should be retained to study possible tunnel routes and points of emergence in a lake. A longer gallery is less expensive than an unfortunate piercing site.

Especial care must be exercised in determining the nature of the banks. Soundings should be taken, particularly in areas where bare rock plunges steeply below the water, and inspections should be made by submerged electric lights in the clear waters of mountain lakes. These activities must be supplemented by borings to determine the amount and character of any detritus at or above potential piercing points.

Whether the lake is to be pierced or to be developed by other means, consideration should be given to the changes which may be expected to accompany the disturbance of equilibrium. Influent streams will rework their deltas carrying fine materials lakeward under the increased gradients that will result from lowered water levels. Sudden drawdowns of the lake, which are of course to be expected in seasonal storage operation, are likely to set off avalanches since they result in the withdrawal of buoyant forces while leaving the hydrostatic pressures and lubricating qualities of pore water a few feet from the banks. In exceptional circumstances such redeposition could create dams which would reduce the effective storage of a lake-reservoir severely. [1927-2].*

Such topographic readjustments seldom reduce the storage capacity of a lake. While they may increase evaporation potential somewhat by increasing the surface area, even this effect tends to be slight since slides occur on the steeper banks. The long-range result may even be slightly beneficial in raising the average head at the power house if this latter operates directly on lake pressure.

One must, of course, be certain that the outlet is kept above the final position of the lake bottom and out of the paths of potential landslides. The dangers to life and property associated with avalanches must also be considered in the location of housing, workshops, access roads, and power lines. Waves resulting

* Numbers in brackets refer to the bibliography at the end of the article.

from slides have damaged pumping barges and even killed members of their crews. [Davos, Gosau].

Studies of water quality at depth should be made to anticipate possible concentrations of poisons which might kill or blind miners [Lac de la Girotte], and lead to litigation with downstream users when the polluted waters are discharged. Litigation over timing of releases is unlikely since the effect of a storage reservoir is almost always to improve the flow regime for downstream owners.

Alternations in water level and the attendant fluctuations of the water table may result in the rotting of piles and of submerged tree trunks, and may lead to claims for actual or alleged damage to agricultural and domestic water supplies. Such problems, while of less importance than those associated with reservoirs created by dams, should not be overlooked. If, as is frequently the case with a pierced lake, interbasin diversions are involved, legal questions arise and these should be settled early.

The type of installation and the depth of intake to be used depend on geological and economic considerations. The relative merits of dams, tunnels, pumping plants, and siphons, either alone or in combination, must be weighed.

Methods of Development

The problem of removing water from a natural lake has several different solutions. These may be classified as follows:—

Methods which depend on lowering the outlet

1. Tunnelling to the lake with removal of the final plug by blasting. [B in the table].
2. Tunnelling to the lake with the connection made "in the dry" behind a cofferdam or in a compressed-air chamber. [C].
3. Ditching or dredging at the natural outlet or elsewhere to create an artificial canyon. [D].

Methods which involve lifting the water over the barrier.

4. Pumping. [P].
5. Siphons. [S].

Blasting, the most spectacular of these methods, is usually to be preferred wherever the terrain is sound enough to make tunnelling safe and rapid. The typical procedure in a lake piercing of this class is to tunnel on a grade rising slightly toward the lake. In the immediate vicinity of the shore one or two vertical shafts are sunk to meet the tunnel, these shafts serving later to house gates and screens. Work, then, may proceed on three or more headings simultaneously.

The point of emergence of the tunnel into the lake will have been selected to be as free as possible of detritus—both that present at the time of the survey and that which might move to the opening under the shocks of explosions and the destruction of equilibrium resulting from drawdown. In many cases, tunnels have been given sharp changes in direction or grade near the lake so that they would emerge just above a talus slope or would avoid some other form of bad ground. In such cases, final trimming to grade is done after the lake has been drained through the temporary opening. On several projects loose material has been removed by dredging or by draglines.

Nearly every description of a lake piercing emphasises the increasing vigilance which accompanies the approach to the final breakthrough. Exploratory drilling is intensified to seek irregularities in the wall contours, explosive charges are reduced to avoid damaging the rock that is to be left in place, and injections to stop seepage are placed more carefully and more promptly. Under protection of only the final plug, a pit is dug in the floor of the tunnel to provide a trap for rock fragments which might otherwise obstruct the passage. Temporary bulkheads of reinforced concrete, with openings covered by steel plates, are placed downstream of the gates. These latter are raised clear of possible damage. Often the gate shaft and the tunnel from plug to bulkhead are flooded with the water surface being some feet higher than that of the lake so that the rush of water following the blast is out of, rather than into, the tunnel. If all goes well the blast may be fired, the gates lowered, the bulkhead removed, and the gates then raised to bring a power plant on the line. If it doesn't—one of the expedients described in the bibliography may be helpful.

It has not always been possible to save the lake water at the time of the blasting. In fact, in many cases no attempt was made to do so. With the lake drawn down to tunnel level, grilles, gates and lining may be put in final shape for a long period of future storage.

Work behind cofferdams or in compressed-air chambers removes some of the risk from geological surprises. It also permits tunnelling in terrain that could not be rendered sufficiently impermeable or sufficiently stable for the blasting of a final plug. An excellent example of a situation justifying compressed-air caissons was the enlarging of the outlets through Lages dam, Brazil, to accompany greatly increased storage which resulted from a raising of the dam. [1949-2,3]. These methods tend to be more expensive than blasting in direct costs in time.

Ditching or dredging involves the later construction of a short dam in the canyon formed and entails the loss of the lake storage on the first draw down. For lakes where a tunnel would not be used to place a penstock under pressure, this loss might well be of no importance since the rate of release could be controlled to match that desired. The method is particularly applicable for connecting several lakes in a basin to permit integrated operation.

Pumping and the use of siphons are often employed as temporary expedients for dewatering a lake to permit tunnelling with both portals dry. These procedures, however, have been adopted as permanent features of a few installations. If the water may be pumped to a forebay pond, the operation is evidently that of a "part-head" pumped-storage project. If not, the power required for the pumps must be supplied while the hydro-electric plant is operating.

Where the final outlet is to be an appreciable distance below the normal water level of the lake, development by steps is common. The procedure usually preferred where the ultimate development has been foreseen at the time of the first tapping is to finish the vertical gate shaft and all works downstream from it. Successive short tunnels may then be pushed from the shaft to the lake and opened in turn by blasting or in the dry. In this latter case, floating pumps may be used with the vertical distance between steps corresponding to the effective head of the pumps employed. [1958-1].

Related Problems

The lakes summarised in the table at the end of this paper were all, or nearly all, developed primarily for storage on power projects. Some of the problems encountered, however, are so closely related to those found in other fields that a mention of them may be helpful.

A number of cities obtain their water supply from wide rivers or large lakes. The quality of such water, of course, is apt to be much better at some distance from shore. The desirability of keeping the intake structure and pipeline free of ice troubles and of avoiding interference with navigation has often led to subaqueous tunnels connecting submerged intakes with on-shore pumping stations. Such installations have usually involved extensive working in compressed air.

Flooded mines have been drained by tunnels providing gravity flow to some low-lying area in their vicinity. The precautionary measures to be taken when working underground near flooded mines are the same as those taken in lake piercing. [1895-1,2,3. 1929-3,4. 1934-1. 1956-9].

Tunnel spillways such as those at Boulder dam are similar in many respects to lake piercings made under protection of cofferdams or made after preliminary drainage by pumps or siphons. One of the most delicate plug blastings ever undertaken, that at Sautet, was at a project where the original plans had called for a simple diversion tunnel above river level. The final holing-through, however, of a plug 27 ft. in diameter had to be made under a head of nearly 50 ft. of water because of obstructions which had raised the downstream river level by more than this amount. [1933-4. 1952-3].

The removal of Ripple Rock, a submerged hazard to navigation in the straits between Vancouver Island and the mainland of British Columbia, was accomplished in the summer of 1957 by tunnelling from the mainland into the rock and then shattering this latter with a devastating explosion.

Créplet's Paradox

If a given lake were to be converted into a reservoir capable of storing its entire annual inflow it would seem evident that more power would result from a development by dam which placed all the stored water above the natural lake level, than from one by piercing which placed all storage volume below. That such a conclusion may sometimes be false was pointed out by J. L. Créplet in a series of studies on the proper utilisation of Lac Kivu in the Belgian Congo. The key to the paradox lies in the evaporation from a larger or smaller exposed surface in the two cases. In proposals made for the piercing of Lake Titicaca, Peru [1906-1] and Lake Sevan, Russia [1957-3] virtually the entire flow through the power house, after the initial period of drawdown from long-time storage has ended, will be obtained at the expense of evaporation.

The Outlook for Lake Piercing

With increasing emphasis on the peak-carrying value of water power when backed by large reserves of stored water, and with the modern improvements in tunnelling (WATER POWER has cited many in its ten years of publication) which have led to lower and more predictable costs, it is reasonable to assume that many a plug will yet be blown. The future of such developments along the fjords of Norway, Alaska, and New Zealand and in rugged mountainous terrains wherever found, thus seems assured. We await with greater interest the tapping of Kivu, Titicaca, Sevan, Hazar [1956-6], or some other of the world's huge lakes followed by a period of years in which draught from storage actually increases the sustained-yield value of the lake remaining. The challenge of diverting water stored above deserts from its present loss by evaporation to the uses of power, irrigation, and domestic water supply cannot be neglected much longer.

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With few exceptions, the literature on lake piercing consists of descriptions of individual projects. The emphasis is often on some other feature of the development and the data relating to the piercing may be vague or absent. A glance at the gaps and, especially, at the contradictory figures in the accompanying table will indicate the difficulties facing the historian of tapped lakes.

The bibliography is obviously incomplete. A paper which merely alluded to some lake which was mentioned nowhere else is cited, whereas only works of major significance are listed if they referred only to such well-documented projects as those of Lochs Fannich and Treig. No adequate index exists and thus some excellent papers may have gone undetected in this study. The author would be pleased to have these called to his attention so that they might be cited in an addendum.

L'Électricité de France kindly furnished a copy of their publication "Percement des Lacs" [1953-2] which contains a valuable discussion and an extensive bibliography. Other general discussions of the field were published by Malan [1938-2], Indri [1939-2] Schiffmann [1942-2], and Créplet [1951-1].

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(References continued on page 307)

Lakes Developed by Piercing or Related Methods

Country and lake	Date	Depth (ft.)	Class*	Dam (ft.)	References	Notes
AUSTRIA						
1 Achensee	1924 (Pr)	46	D		1924—1	
	1925–26	43	C		1942—2	
2 Forstsee	1924–25	82	C2		1942—2	
3 Gosausee		131	P	79	1930—4 (vague)	Dam dates from 1910
	1928	99	P		1942—2	
		197	P	76±	1956—4	Subterranean pump
4 Lünersee		171	B		1942—2	
5 Pochard		20	B		1924—1	
6 Spullersee	1920	36	B		1924—1	
	1920	62	B		1942—2	
7 Zürsersee	1940	7	D		1942—2	
AUSTRALIA—Tasmania						
8 Margaret	1914	16	D		1916—3, 4	Dam provided for
BELGIAN CONGO						
9 Kivu	Project	98			1949—1, 1951—1 1953—1	
BRAZIL						
10 Lages Dam	1944	150	C		1949—2	Cofferdam sealed to face of old dam
	1944	177	C		1949—3	
CANADA—Ontario						
11 Finlayson	1944	60	B		1944—1	
					1943—2	In use in 1943
12 Long	1943		B		1943—2	
13 Marmion	1944	41?	B		1944—1	
14 Raft	1944	75	P		1944—1	Tunnels in dry to Finlayson and Marmion
15 Steep Rock	1944	100+	P		1944—1	Pump out to unwater ore
CANADA—Yukon						
16 Sloko	Project				1957—1	
CHILE						
17 Invernade				148	1950—2	
		97			1957—2	Dam to be added
18 Laja	Project	82	B?	low	1950—2	
19 Noir	Proposed	105	B		1877—1	
FRANCE						
20 Araing	1934	66	B		1938—2	
	1934	95	B		1942—2	Cites only 1938—2
21 Artouste	1927	162	B3	72	1928—2, 1938—2	
	1924–25	163	B3		1942—2	
22 Aumar		23	D		1920—1	
23 Blanc		69	B		1901—2	Under construction 1901
		66	B		1902—3	Judicial delay
	Existing				1933—1, 1939—2	
	1933	66	P		1942—2	
24 Bleu (1)	1851		S		1916—6	
(2)		66			1916—6	
25 Bramant	1918	59	B, D		1927—3, 1938—2	Piercing failed
			B, S		1942—2	Cites only 1938—2
26 Caillaouas (1) ...	1896	61	B		1901—1	
(1) ...	1898	56	B		1933—2, 3	
					1938—2, 1953—2	
(2) ...	1932	222	P4	44	1933—2, 3	Three additional steps
					1938—2, 1953—2	
(2) ...	1932	168	B		1942—2	
27 Campana		128			1944—2	
28 Cap de Long ...		31	B	26	1904—1	Under construction 1904
		33	B	26	1920—1	
29 Carré	Proposed	69	B	26	1902—3	
	1917?	70	B	27	1925—4	
30 Chalain	1904?		B		1904—2	
		46			1914—2	
31 Cotepan	Proposed	85	B	10	1902—3	
	1917?	82	B	16	1925—4	Siphon proposed to lift over a bar in the lake
	Pre-war	98			1938—2, 1942—2	Rock bar blasted in dry

* B—Plug removed by blasting; C—Cofferdam used; D—Ditching or dredging; P—Pumping; S—Siphons Numbers indicate number of steps.

Lakes Developed by Piercing or Related Methods (continued)

Country and lake	Date	Depth (ft.)	Class	Dam (ft.)	References	Notes
FRANCE (continued)						
32 Crozet	1897	89	B	16	1901—2, 1902—3	
33 En-Bays					1920—3	Tunnel
34 La Girotte	Proposed	49	D		1902—3	
(1)	1900	53		13	1925—7	
(2)	1925	101	B		1925—7	
(3)	Pending	102	B		1925—7	
(3)	1927	116	B		1927—3, 1928—1	
					1938—2	
		358	Total		1948—1	Provision for 36 ft. more by raising dam in future
35 Glacé	Project	98	B	16	1931—1	
36 Gréziolles		66	B	79	1944—2	Dam to be added later
37 Issarles	1953	165	B, P		1951—2, 1954—1	Blasting 122 ft.
					1956—2, 7	Pumping 43 ft.
38 des Laquets		26	B	43	1944—2	
39 Migoëlou	1936	98	B, D6	49	1938—2, 3	Blasting 72 ft.
						Trenching 26 ft. (6 steps)
		72	B		1942—2	Cites only 1938—2
40 Mort	1933	66+	B, D		1938—2, 1942—2, 3	Blasting 66 ft.
41 Naguilhe		35	B	46	1917—1	
		56	B	33	1920—3	
42 Oô	1920?	131		33	1925—5	
		134	B	31	1927—2	
	1921	296	B		1938—2, 1942—2, 3	
43 Orédon		39	B	17	1881—1	
	1885?	23	D	55	1917—1, 1920—1	
44 Pont du Loup ...	1934		B		1938—2, 1942—3	
45 Portillon	Project	164	B	49	1931—1	
	1929				1938—2	
			B		1942—2	
		160	B	65	1950—1	1941 or earlier
46 Salé	1932	98	B		1938—2, 1942—2	
GERMANY						
47 Bockhartsee					1942—2	
48 Schluchsee		49	B		1939—2	
	1930	43	B		1942—2, 3	
49 Walchensee	Proposal	66			1909—1	Intl. competition invited
		33	D		1924—1	
		15	D		1942—2	
50 Weiss	1942	66	B		1942—2	
GUATEMALA						
51 Atitlán	Project				1956—5	
ITALY						
52 Alban	395		D		1942—2	Oldest known case
53 Alleghe		42	C?		1939—2, 1942—2	
54 Antrona			S		1939—2	Several steps
	1926	62	SPD		1942—2	
55 Arno		108	CP	66	1911—1, 2	82 ft. pierced, 26 ft. pumped
	1911	105	CP	82	1912—2	Dam under construction
		82	C		1942—2	
			CP		1953—2	
56 Cavedine		16	D		1939—2	
	1925–26	43	C?		1942—2	
57 Fucinus		5	D		1942—2	Time of Claudius
58 Ledro	1928	70	B		1928—3	
		87			1929—1	
	1926	79	B		1942—2	
59 Molveno		393	P	49	1953—3	Several steps. Two shafts
	1952–53	380		16	1958—1	
60 Moncenisio			D		1939—2	Partly by dam
		20			1942—2	
61 Nemi			P		1939—2, 1940—2	
62 Santa Croce (1) ...	1913				1924—2	Two dams to complete project
(2) ...	1923	65	BD		1924—2	
					1928—4, 1942—2	Total: 107 ft.
63 Truzzo	1924–25	98	B	66	1925—1, 6	Lake drained in 131 hours
JAVA						
64 Kloët	1925?	176	S7		1939—2	
	1923–25	197	S		1942—2, 3	
NEW ZEALAND						
65 Coleridge	1912–15	12?	B		1912—1, 3, 1915—2	
		20?			1916—1	
66 Kanieri					1915—2, 1916—1	

Lakes Developed by Piercing or Related Methods (continued)

Country and lake	Date	Depth (ft.)	Class	Dam (ft.)	References	Notes
NEW ZEALAND (continued)						
67 Rotoiti					1955—2	Exploratory drilling 1955
68 Waikaremoana ...					1956—3	
NORWAY						
69 Berso	1914?	89	B		1914—3	
		59			1924—3	
70 Glomvand	Project	52		26	1923—3	
					1930—3	"Nearly 100 feet"
71 Hagedalsvann ...	1932	26	B		1941—2, 1942—2	
72 Heröya	1935	66			1941—2	Tailrace into open sea
	1935	72	B		1942—2	
73 Kvittingen	1909–12	85	B	23	1912—4, 1913—1	Six more lakes to be pierced in ultimate development
74 Markevann	1938	92	B		1941—2, 1942—2	
75 Moor					1942—2	
76 Navann	1932	56	B		1941—2, 1942—2	
77 Osbu		26		76	1956—8	Dam under construction
78 Ringedals (1) ...	1895				1909—2	Original project abandoned
(2) ...	1907	53		45	1909—2, 1911—3	Completed by divers
(3) ...	1914?			102	1914—3	Second tunnel, raised dam
(2) ...	1907	66		low	1952—1	
(3) ...				108	1924—3, 1952—1	
79 Skorgevann	1938	101	B		1941—4, 1942—2, 3	
					1953—2	
80 Storevand		33		8	1921—2	
PERU						
81 Titicaca	Proposal				1906—1	
RUSSIA						
82 Sevan	Project				1957—3	
SCOTLAND						
83 Fannich	1950	81	B		1951—4, 5, 1950—3, 1953—2	Additional 20 ft. by dam proposed 1951–3
84 Treig	1930	104	B	35	1928—3, 1930—3, 5, 6, 1937—1, 1938—1, 1941—1, 1953—2	
SPAIN						
85 Colomina	1926?	105	B		1927—1, 1942—2	
86 Fossée		98	B3	16	1939—2, 1942—2	
87 Mar	1926?	167	B		1927—1	
		170	B		1942—2	
88 Saburo	1926	204	B2		1927—1, 1942—2	
SWITZERLAND						
89 Arnon	1921	82	PS		1923—2	Several steps
				3	1943—1	1 metre dam added
		115	B		1942—2	Cites only 1923—2
		115			1953—2	
90 Bernina		85	P	18	1930—1	
(Lago Bianco	1923		P	36	1930—7	5 ft. dam raising proposed
and Lago della		66			1939—2	
Scala)	1910–12	18	P		1942—2	
91 Brenet	1903	16	D		1904—3, 1942—1	
(Lac de Joux)					1924—1	
92 Davos	1924?	113	P	20	1939—2, 1942—2	
	1923	92	P	26	1922—1, 2	Dam in steps: 20 ft., 6 ft.
93 Fully	1914	33	B		1942—2	
		59		64	1911—4	2 floating pumps used
94 Klönthaler		25?	P	74	1939—2	Pierced at 5 ft., pump head 20 ft.
		25?	P			
	1908–9				1942—2	
95 Kubelwerk			S		1924—1	
96 Lucendro	1944	66		220	1945—1	
97 Lungernsee	1836	133	B		1942—2	
98 Palpuognasee ...	1916	6			1942—2	
99 Poschiavo	1906	24	S	3	1908—1, 2, 3, 1910—1	
		33	C?		1942—2	Credited to Italy
100 Ritom	1917	98	B		1917—2, 1942—2	
		98	B	23	1920—2	

Lakes Developed by Piercing or Related Methods (continued)

Country and lake	Date	Depth (ft.)	Class	Dam (ft.)	References	Notes
SWITZERLAND (continued)						
101 Tanay (1)	1901	85?			1902—1, 2, 3	Intercepted natural drainway
(2)	1934	72?	B		1943—1	
102 Tremorgio	1918	94	B		1925—8	Several blasts to clear debris
		85			1942—2	
TURKEY						
103 Hazar	Project	82			1956—6	
UNITED STATES—Alaska						
104 Annex	1916	150	B		1916—5	Blown without disturbing valves
105 Cooper	Proposed	50?			1955—1	
106 Crescent	Proposed	50?			1955—1	
107 Eklutna		64?			1952—2	Under construction 1952
		60		7·5	1956—1	Intake set by divers
	1953				1954—2	Intake by dredging and diving
108 Grant	Proposed	50?			1955—1	
109 Long	Proposed	12		25	1914—1, 1915—1	
110 Ptarmigan	Proposed	50?			1955—1	
111 Upper Silvis		70	B		1946—1	Under construction 1946
UNITED STATES—California						
112 Manzanita	Proposed	20		5	1923—1	Dam built in 1911
UNITED STATES—Colorado						
113 Hope		120	B	20	1911—5	
	Late '90's	113	B	10	1929—2	
UNITED STATES—Idaho						
114 Boulder	1922?	10?		6	1935—1	
115 Granite		8		19	1935—1	
UNITED STATES—Montana						
116 Mystic		48	B	20	1926—1	Dam proposed
	1923–24	40	B	20	1926—2	
		49±			1926—3	Dam proposed
		43	B		1942—2	
UNITED STATES—Oregon						
117 Killamacue		24		11	1935—1	
118 Olive	1915		P	34	1916—2	
UNITED STATES—Washington						
119 Snow	1939–40	165	B		1940—1, 3, 1941—1	
UNITED STATES—Mississippi Valley						
120 McKinney		8	S		1892—1	Lift 18·5 ft., fall 26·5 ft.
WALES						
121 Eigiau	Project				1906—2	
122 Llydaw		30	B	20	1904—4	"Being developed" 1904
		30			1906—2	"Has been cut." Dam later
LOCATION UNSPECIFIED						
123 Avio (Italy?) ...		61	B	98	1939—2	
124 Idro					1939—2	
125 Matese					1939—2	
126 Obersee		13	DS		1939—2	
(Bacino della Toce)						
127 Piazze					1939—2	
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Further Research on Bolted Angle Structures

A number of simple frames made of bolted angles has been made and tested. Strains in the members were measured, and in each case, the Southwell Plot on strains proved to be a straight line. The equation of this linear plot defines the behaviour of the strut in the elastic range, and can be used as a criterion of the load carrying capacity

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THIS article records the results of further research on bolted angle structures for transmission-line towers undertaken subsequently to that described in the author's article in the January issue of WATER POWER.

Five trusses (L2 to L6) were made up and tested as in Fig. 1. The flange members $U_o U_5$ and $L_1 L_6$ were single $1 \times 1 \times \frac{1}{8}$ in. M.S. angles. The web members $U_o L_1$, $U_5 L_5$, etc., were $0{\cdot}58 \times 0{\cdot}58 \times 0{\cdot}036$ in. aluminium angles. The members were bolted together with $\frac{1}{8}$ in. metal threads, through holes drilled in the centre of the angle leg; the bolts were tightened to a predetermined torque, in an attempt to get a constant fixing.

During loading, longitudinal strains were measured in the web compression members at the corners of the angles (see Fig. 2). It was found that this corner

TABLE I

Truss	Web Member				Q_1 (lb.)	$C_1 \times 10^6$ (lb.$^{-1}$)	$\eta_1 = EAC_1$	Member	Effective length = $\sqrt{\frac{\text{Euler load}}{Q_1}}$
	Length (in.)	l/r	Failure load P (lb.)	"Failure" strain ϵ					
L_1	15·45	130	180	·0013	230 240	1·8 2·3	0·65 0·84	L3U2(i) L3U4(o)*	0·93
L_2	15·45	130	103	·0013	280 200 174 174	2·7 1·2 3·0 4·1	0·98 0·44 1·09 1·49	UoL1(i) U1L2(i) U4L4(o) U5L5(o)*	1·10
L_3	15·45	130	100	·0013	140 140 124 112	1·1 0·8 1·6 1·9	0·40 0·29 0·58 0·69	UoL1(i) U1L2(i) U4L4(o) U5L5(o)*	1·37
L_4	10·13	85	160	·0013	320 320 320 320	1·4 0·8 2·5 2·9	0·51 0·29 0·91 1·06	UoL1(i) U1L2(i) U4L4(o) U5L5(o)*	1·22
L_5	10·13	85	155	·0018	220 220 220 220	1·0 1·3 1·7 2·3	0·36 0·47 0·61 0·82	UoL1(i) U1L2(i) U4L4(o) U5L5(o)*	1·48
L_6	10·13	85	180	·0016	360 360 260 260	1·4 1·1 1·9 1·9	0·51 0·40 0·69 0·69	UoL1(i) U1L2(i) U4L4(o) U5L5(o)*	1·36

NOTE: (1) * indicates member that failed.
(2) Truss L1 is reported in reference (3).
(3) "o" indicates that member was bolted on outside of flange member; "i," on inside.

was always the most highly stressed point in the angle under the loading conditions adopted.

Fig. 3 shows a typical set of graphs of strain ϵ, against applied load W, or the load in the struts P. Similar graphs were obtained in each case. On these graphs, the calculated average axial strain P/EA is also shown.

P = the axial load in the member $= W/\cos\theta$.

E = Young's modulus = 9,000,000 lb. per sq. in.

A = cross-sectional area of the member = 0·0403 sq. in.

Fig. 4 shows the corresponding Southwell Plots on the strains. It was found that the graphs of $(\epsilon - P/EA)/P$ against $(\epsilon - P/EA)$ consistently gave straight lines. Again, the plots in Fig. 4 are typical of sets of straight lines obtained for every compression member in every truss tested.

The equations of these lines may be written

$$\frac{\epsilon - P/EA}{P} = \frac{\epsilon - P/EA}{Q_1} + C_1 \quad \ldots (1)$$

where ϵ = the measured maximum strain at the centre of the member.

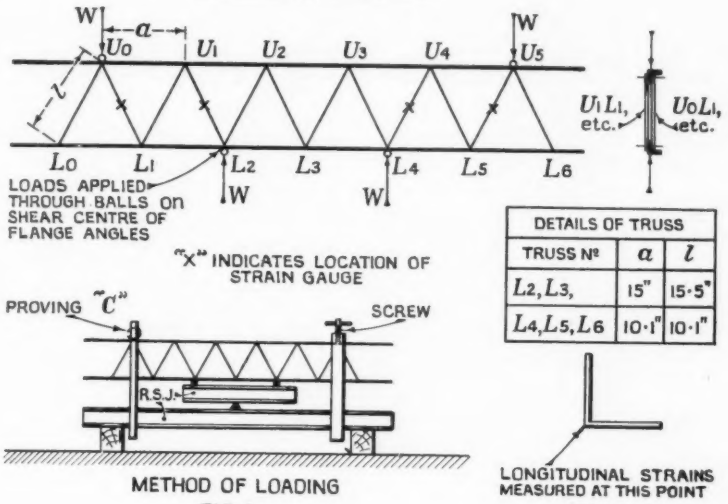
P = the measured strain minus the average strain (or the "bending strain").

P/EA = the axial load in the member.

Q_1 = the inverse slope of the Southwell Plot.

C_1 = the intercept of the Plot on the strain/load axis.

Equation (1) reduces to



METHOD OF LOADING

FIG. 1

DETAILS OF TRUSS		
TRUSS Nº	a	l
L_2, L_3,	15"	15·5"
L_4, L_5, L_6	10·1"	10·1"

LONGITUDINAL STRAINS MEASURED AT THIS POINT

FIG. 2

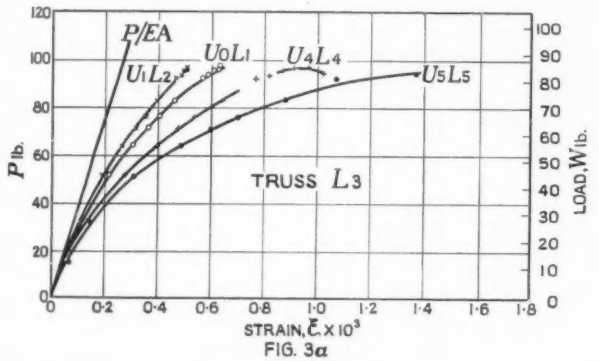


FIG. 3a

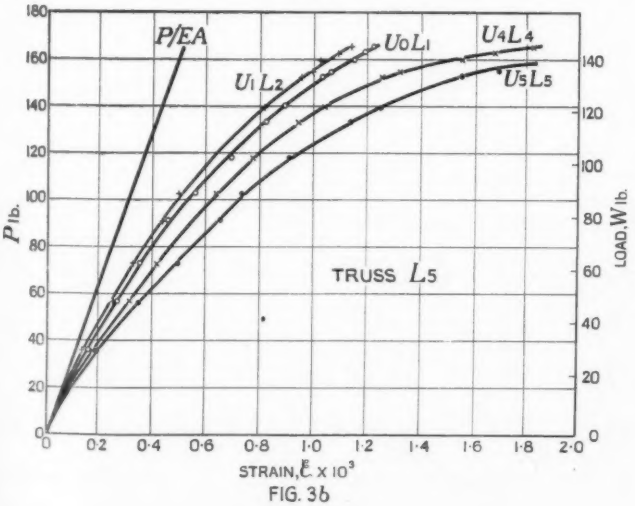


FIG. 3b

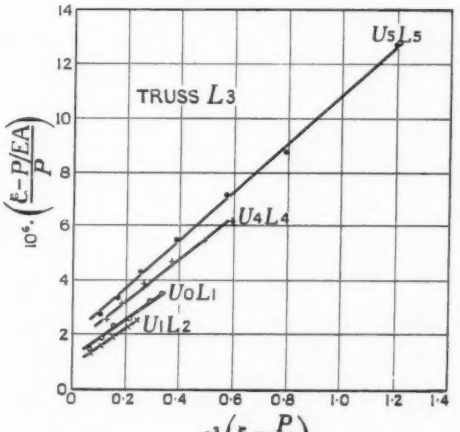


FIG. 4a

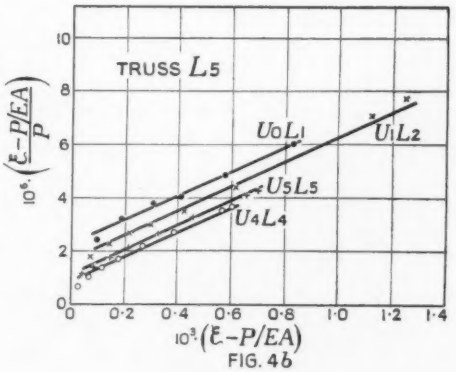


FIG. 4b

$$\frac{EA\epsilon - P}{P} = \frac{EA\epsilon - P}{Q_1} + EAC_1$$

$$\therefore\ EA\epsilon\left(\frac{1}{P} - \frac{1}{Q_1}\right) = 1 - \frac{P}{Q_1} + EAC_1$$

$$\therefore\ E\epsilon = \frac{1}{A}\left(\frac{Q_1 P}{Q_1 - P}\right)\left[\frac{Q_1 - P}{Q_1} + EAC_1\right]$$

$$= \frac{P}{A}\left[1 + EAC_1\,\frac{Q_1}{Q_1 - P}\right]$$

$$\text{or } E\epsilon = \frac{P}{A}\left[1 + \eta_1\,\frac{Q_1}{Q_1 - P}\right] \qquad \ldots (2)$$

where $\eta_1 = EAC_1$

The usual code formula for columns is obtained from $f_{max.} = f_{Y.P.} = \frac{P}{A}\left(1 + \eta\,\frac{Q}{Q - P}\right)$ where η is an assumed crookedness factor, and Q is the Euler load of an assumed effective length.

A sufficient number of tests on many types of structures should give values of Q_1 and η_1 likely to be met with in practice. These values obtained from the Southwell Plot on strains can be used to give a design formula similar to equation (2), based on actual tests, not on arbitrarily assumed factors.

The test results are summarised in Table I.

It is seen that there is quite a wide variation in values of Q_1 and η_1, even under apparently similar conditions. It is suggested that this may be due to the varying torsional stiffness of the flange angles. The restraint which the flange angle affords a web angle depends a good deal on the location of the latter. Also, new bolts were used in some trusses and not in others, and the fixing may have varied.

In spite of this variation, the following important conclusions can be drawn:

1. The behaviour of each compression member tested can be defined by Q_1 and η_1. These factors may vary somewhat, but it is important to carry out sufficient tests to determine the maximum value of η_1 and the minimum value of Q_1 for each type of fixing in each type of structure.

2. Maximum load carrying capacity for this material occurs at a strain of 0·0013. The Southwell Plot is linear up to this strain, and there is very little reserve of strength beyond this point. For the aluminium members concerned, equation (2) reduces to $\frac{P}{A}\left(1 + \eta_1\frac{Q_1}{Q_1 - P}\right) = E\epsilon = 12{,}700$ lb. per sq. in.

In the case of mild-steel members, the yield stress is substituted for $E\epsilon$, and P becomes the load to cause first yield. Due to the high value of η_1, this is for all practical purposes the failure load for bolted angles struts.

It has been shown that the axial loads P, in rigidly jointed trusses can be calculated with sufficient accuracy by assuming pin-joints. The above method thus furnishes a direct design method for statically determinate braced frameworks.

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Transmission Lines. The Imatra Power Company, of Helsinki, Finland, have sent us a publication which describes some of their typical transmission lines, the design of which has been widely approved. Details are given of 110 kV, 220 kV and 400 kV lines in Finland, which are of considerable length in view of the distances that exist between the hydro-electric power stations and the chief points of consumption.

Fig. 1. Periyar dam, built 65 years ago, was the first high dam in India. It is 176 ft. high

Periyar Project

A description of the Periyar hydro-electric project in Madras State, India

By R. DORAI RAJAN

THE Periyar project utilises a reservoir of the same name which was built 65 years ago. The Periyar river is the largest in Kerala and is about 130 miles long. Apart from providing water for irrigation the river has great power potentialities both in Madras and Kerala. In this connection the Idikki project, estimated to develop about 400,000 kW is now being investigated.

The Periyar reservoir was built for irrigation purposes 70 years ago and is 176 ft. high. It commands a catchment area of 232·83 sq. miles with an average rainfall of 100 in. in the valley and 200 in. in the adjoining mountains. At the full reservoir level of 152 ft. the storage amounts to 15,662 million cu. ft. of which about 10,000 million cu. ft. is live. The surface area of the lake is 10·21 sq. miles. The dam is of the gravity non-overflow type, is built of surki masonry and is constructed without the usual expansion joints or drainage gallery, which were unknown at that time. Even so it has stood the test of time very well indeed and the leakage is negligible.

From the Periyar reservoir the water flows through a 5,794 ft. long tunnel under a ridge and emerges on the Madras side where it pours down a natural valley to irrigate 143,000 acres in the Madura district. This tunnel was constructed about 60 years ago with hand boring and gunpowder.

Soon after the Periyar reservoir was completed the possibility of utilising the water for power development was examined by an expert committee with which Colonel Pennyquick, the engineer who constructed the dam, was associated. The report, which was encouraging, suggested that the power could be used to manufacture calcium carbide and aluminium but nothing was done at that time because of certain difficulties raised by the Travancore Government and it was not until 1954 that an agreement was reached. The Periyar project thus started with the advantage of having a water-storage system before the power scheme was started. The original capacity of the tunnel, however, was only 1,300 cusecs and had to be enlarged to accommodate a discharge rate of 1,600 cusecs. To this end its cross-sectional area was increased to 200 sq. ft. The invert and about half the length of tunnel were lined with concrete.

The intake end of the tunnel was also lowered 5 ft. and two existing gates replaced by a new emergency gate manufactured by Madras Public Works Department with arrangements for manual as well as electric operation. The regulating gate, installed 200 ft. downstream, has a clear width of 14 ft. and a height of 12 ft. 6 in. It is of roller type and weighs 17·5 tons. The operating platform is 72 ft. above the sill of the gate and electrical hoisting equipment, remotely controlled from the power house, is provided. This was supplied by the M.A.N. concern of Germany. At the exit end a new intermediate dam 260 ft. long and 100 ft. high has been constructed for regulation pur-

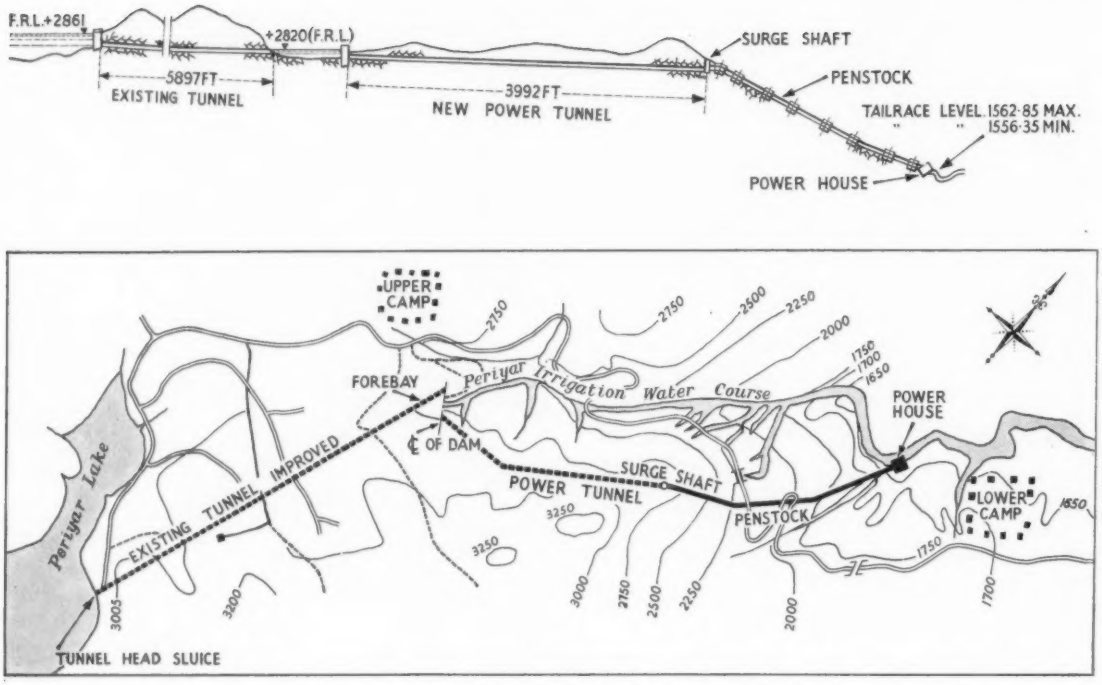


Fig. 2. Map and profile of the Periyar project

poses, the capacity being 3 million cu. ft. It is built in three blocks with a central overflow section 45 ft. wide. The spillway has no crest gates. An under-scour sluice 10 ft. by 8 ft. is provided on the right bank and the power penstock consists of a 13 ft. diameter steel pipe. The scour sluice gate is also of roller type and is designed for a 90 ft. head. All the hoisting equipment is installed on a gantry running along the crest of the dam. The penstock and trash rack were also supplied by M.A.N. of Germany.

From this intermediate dam the water flows through a new power tunnel of horse-shoe shape, 3,992 ft. long and having a cross-sectional area of 151 sq. ft. This tunnel measures 14 ft. by 12 ft. 10 in. and has a slope of 1 in 100. It is driven through hard granite rock and is unlined except in a small reach about 100 ft. long which had to be supported. The surge shaft is 150 ft. high and 49 ft. in diameter and is entirely excavated in rock; it is lined with concrete.

Two low pressure pipes, 10 ft. in diameter and 194 ft. long, take the flow to a valve house where each bifurcates into 6 ft. 6 in. in diameter branches. Three penstocks are provided at present and the fourth is flanged off for use at a later date. The penstock pipes are 3,180 ft. long and their diameters range from 78 in. at the top to 45 in. at the power house. Each is designed to carry 400 cusecs. In the upper reaches the pipes are constructed of ordinary standard steel, but the higher pressure portions are made of high-tensile steel with a view to reducing the thickness and weight of the pipes. These are of welded construction; they were received in lengths of 20 ft. and were erected at site by technicians from the Sakai Iron Works Limited, Japan, who supplied them.

At the head of each penstock a 78 in. butterfly valve and an air valve are installed. Besides provision for operation at the valve house, electrically operated remote control is provided from the

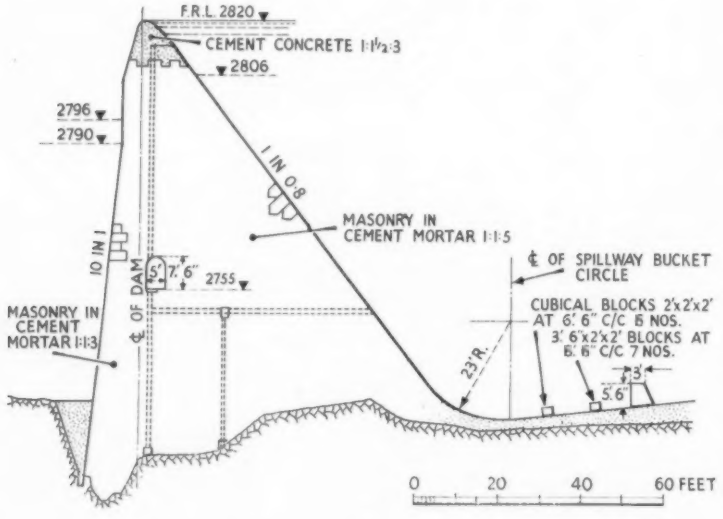


Fig. 3. Overflow section of the forebay dam

Fig. 4. Periyar penstocks, power station and switchyard

power house. The rotary valves controlling the turbines are 45 in. in diameter and weigh 15 tons. They are designed for a net head of 1,263 ft.

The power house building, 200 ft. long, 55 ft. wide and 70 ft. high, is a steel-framed structure with a reinforced concrete roof and the wall panels filled in with masonry work. The structural steel was supplied by S.A.E. of Italy. Provision is made for a fourth machine. A 100 ton electrically operated travelling crane, supplied by Nixex Hungarian Trading Corporation, is provided and runs on track rails fixed over gantry girders which, in turn, are fixed to the steel frame of the building. The control equipment is installed in an annexe.

In spite of the high head it was decided to install three Francis type turbines manufactured by J. M. Voith of Germany. These have a speed of 750 r.p.m. and are each capable of developing 55,000 h.p. when discharging 403 cusecs under an effective head of 1,225 ft. The spiral casings of the turbines are of welded construction and are provided with a steel-plate connection to join up with the concrete draft tubes.

The turbines are vertically coupled to 35,000 kW A.E.G. generators having a power factor of 0·85. The power is generated at 11 kV and is stepped up to 110 kV by 14,000 kVA capacity single-phase transformers manufactured by Oerlikon, each weighing 27 tons.

All three machines will be able to work during the nine months of the irrigation period and one will be able to operate during the non-irrigation season, the tail water being led through the present irrigation channel and stored in the Vagai reservoir about 40 miles downstream.

The outdoor transformer yard is alongside the power house and has 10 Oerlikon single-phase, 14,000 kVA transformers with three units for each generator and one spare. The main structure is of the double-deck type for carrying duplicate 110 kV busbars with necessary cut-off switches.

The power generated at Periyar will be fed into the existing grid through 110 kV and 66 kV lines connecting important towns. New 66 kV substations at Pallapatti, Pudakotta, Karakudi and Paramakudi are in course of construction. There will also be some new 33/11 kV substations for local distribution.

Periyar is the first power project in Madras State where the bulk of the machinery installed is of Continental and Japanese manufacture. The total cost of the scheme is Rs. 10·5 crores. When all three units are working, 105,000 kW will be available during the irrigation period and 35,000 kW in the non-irrigation period. The power will benefit all the southern districts in the State, namely, Mathura, Trichinopoly, Ramnad, Tirunelveli and portions of Coimbatore where a soda ash plant, a new paper mill, an aluminium factory and a number of textile mills are about to be constructed.

A welcome feature of the Periyar development is the assurance by the Madras Electricity Board that there will be no more summer power cuts for some years.

The scheme has been completed well within the scheduled time; it was started early in 1955 and has taken about three and a half years to complete, an accomplishment of which the Madras Electricity Board can take legitimate pride, considering the difficult terrain in which the work had to be done. Mr. V. P. Appadurai, Chief Engineer of the Board, was especially responsible for the early completion of the scheme and he was ably assisted by Mr. G. Venkataraman, Chief Engineer for construction, Mr. H. Raghavendra Rao, Superintending Engineer, was the engineer on site.

Consolidated Pneumatic and the Reichdrill. The Consolidated Pneumatic Tool Co. Ltd., 232 Dawes Road, London, S.W.6, announce that their parent company, the Chicago Pneumatic Tool Company, New York, has acquired the Reich Bros. Manufacturing Co. Inc., of Terre Haute, Ind., U.S.A., producers of the internationally known Reich line of truck and crawler-mounted hydraulic rotary blast-hole drills, and drilling rigs for down-the-hole blast-hole operations. The acquisition also includes the Reichdrill Manufacturing Co. Ltd., Glasgow, and that company will henceforth operate as the Reichdrill Division of Consolidated Pneumatic. As a result of the acquisition, the Consolidated Pneumatic range of equipment now covers the entire field of drilling operations for the construction, petroleum, coal and metal-mining industries.

I.E.C. Committee on Water Turbines

A summary of the proceedings of Technical Committee No. 4 (Hydraulic Turbines) at the Plenary Session of the International Electrotechnical Commission held recently in Madrid

THE International Electrotechnical Commission which assembled in Madrid early in July 1959, provided an opportunity for the Committee dealing with hydraulic turbines, consisting of 50 delegates from 15 nations, including Hungary, Czechoslovakia, Finland, Yugoslavia, U.S.S.R., and Japan, to consider the progress made by Working Groups on tasks which were assigned to them at Zürich in October 1957.

The Working Groups held preliminary meetings from July 1-4 to prepare reports for the formal business between July 6-9 on codes for:

(i) Hydraulic Turbine Model Testing;
(ii) Acceptance Tests for Hydraulic Turbine Governors;
(iii) Commercial Specifications;
(iv) Testing of Pump-Turbines & Storage Pumps;
(v) Hydraulic Turbine Operation and Maintenance.

The Committee were informed of the retirement of Mr. S. Logan Kerr (U.S.A.) as International Chairman and a vote of thanks for his work was accorded. Prof. L. J. Hooper (U.S.A.) was welcomed as his successor.

Field Test Code

Although the sections of the Field Test Code dealing with the Allen salt-velocity, Gibson, and current-meter methods of flow measurement had received approval under the Six Months' Rule, together with requests for detail technical amplification of the first two to bring them into line with the third, only limited progress was reported on the remainder of this document. A preliminary draft, however, was available to Chief Delegates just prior to the meetings and a new Editorial Group was constituted to examine it immediately. This comprises: *Editor-in-Chief:* Prof. H. Gerber (Switzerland); *French Speaking:* M. Kestlicher (Belgium), H. Hug (France), M. Fauconnet (Switzerland); *English Speaking:* F. Lawton (Canada), L. J. Hooper (U.S.A.), S. P. Hutton (United Kingdom). It should be circulated to National Committees by September 30, 1959, for comment preparatory to issue under the Six Months' Rule.

There was some discussion covering procedure for amendments and addition of new material to subsequent editions and on the inaccuracy of different methods of flow measurement, which promises to bring some useful comparative data to the next meeting.

Model Test Code

The multiplicity of comments received from National Committees on the draft "Code for Hydraulic Turbines Using Laboratory Models for Acceptance Tests" demonstrated the importance of this subject and resulted in a new document being presented to the delegates as the basis for review. There was considerable emphasis on the need for uniformity with the Field Test Code, wherever practicable, and this was recognised in giving approval to it, with a number of amendments, for reference to the same Editorial Group as for the Field Test Code with Dr. Hug (France) as Chief Editor.

Surprisingly, there was little technical discussion on such matters as conditions for model/prototype similitude, cavitation, minimum model sizes, scale-effect formulae and their application, although it was evident that keen interest in these topics existed amongst the delegates present. No doubt comment will be forthcoming when the revised draft is circulated.

Since the Field Test Code is to have priority no programme was established for work on the "Model Test Code."

New Work

The Interim Working Groups set up by the Chairman presented reports on four questions where International Codes might be appropriate, two of which were accepted by the Committee, namely:

(i) "*Acceptance Test Code for Pump-Turbines and Storage Pumps.*" A Working Group was agreed for this task comprising five members to be nominated by the International Chairman from Germany (Leader), Italy, Switzerland, U.S.A. and United Kingdom.

(ii) "*Acceptance Test Code for Hydraulic Turbine Governors.*" The scope embraced by this particularly important problem was appreciated by the Committee who recommended the appointment of five members and delegated powers to the International Chairman to co-opt additional specialised personnel, if necessary. The nominations approved were: C. L. Avery (Leader) (U.S.A.), Prof. M. E. Oledal (Sweden), Prof. G. Hutarew (Germany), Dr. H. Hug (France), Prof. M. Nechleba (Czechoslovakia).

(iii) "*Commercial Specifications.*" There were no specific recommendations from the Interim Working Group on this subject, and while the Committee accepted that there might be a wider interest in it outside of the International Electrotechnical Commission, it was apparent that National Committees were, at present, only prepared to consider directives on matters which were strictly technical, and the proposal was declined.

(iv) "*Turbine Operation and Maintenance.*" This item originated from the U.S.S.R. but the Interim Working Group merely suggested an interchange of technical information, which the Committee endorsed, thus leaving the way

open for consideration at a future meeting if investigation established that such a code was justified.

Units of Measurement

Discussions disclosed some interest in the metric units to be used in the Field and Model Test Codes and a Working Group of three was approved to make suitable recommendations for the Second Editions consisting of: S. Ferry (Leader) (France), M. Castillo (Spain), Prof. M. E. Oledal (Sweden).

Conclusions

The time and place of the next meeting was left to the Chairman to decide in consultation with the National Committees. It is apparent that although the Editorial Group faces a formidable task in finalising both Field and Model Test Codes, these, together with proposals for acceptance test codes for pump-turbines and storage pumps and hydraulic turbine governors, should warrant a meeting of The Hydraulic Turbine Committee before the next Plenary Session of the International Electrotechnical Commission in New Delhi in November 1961. The spirit of international goodwill was very marked at Madrid and promises well for the future, which will, perhaps, offer more technical matters for debate in the hydraulic machinery field than have been submitted at previous assemblies of the Committee.

Conference on Structural Models

The first International Colloquium on Models of Structures was held in Madrid recently under the auspices of RILEM

THE ever-increasing interest in model techniques used as an alternative analogue computer for solution of complex structural problems has led this year to the first International Colloquium on Models of Structures. This meeting, organised by RILEM (Reunion Internationale des Laboratoires d'Essays sur le Materiaux et les Constructions), was held in Madrid during the last week of June at the invitation of Professor E. Torroja, an engineer and architect of world repute. Although all types of civil-engineering structures were discussed it is of interest to the hydro-electric engineer that the problem of dams figured prominently in the papers presented. The reason for this is perhaps not difficult to establish. Dams, especially those of the modern double-curvature arch type with complex boundary conditions, present problems not amenable to exact mathematical computation. Their relative stiffness allows considerable departure from strict conditions of displacement similarity to be made with impunity and, therefore, model techniques are easily adapted here. In addition, the primary cost of such structures is sufficiently high to allow a suitable sum to be spent on model investigation with subsequently large possible economies. These same reasons have so far limited the use of models in other fields of structural engineering to some extent, but the way to a much wider field of applications was clearly presented.

As the scope of the subject is rather broad the discussions of the conference were divided into five main topics. These were: similitude, materials and methods of construction, loading, measurements, and, finally, the practical interpretation of results. In the notes that follow some remarks will be made on the first four of these (the last not requiring any further stressing for those engineers whose concern is the design of dams).

Similitude

Great interest is being shown in all countries in simulating the behaviour of the structure for loads which cause the material to pass outside the elastic limits and reach the point of rupture. It is here that the model goes well beyond being only a computer, capable of solving rapidly the elastic problems which can at least be formulated mathematically, and becomes a tool by which problems often incapable of exact mathematical formulation can be tackled. The pioneering work in these areas started by Italian engineers is being continued in Portugal and other countries.

Materials

Naturally, this is one of the most important questions facing those connected with model investigation, and the amount of discussion on these topics has continued well beyond the times allocated. The use of plasters with diatomite fillers initiated many years ago by the United States Bureau of Reclamation has now been developed into a standard technique by Portuguese engineers and is being adopted in many other countries. Some possibilities of the use of this material in rupture studies of dams is now being contemplated.

The subject of mortars and micro-concretes, suitable for simulating the inelastic behaviour of the prototype materials was dealt with in many papers. The pioneering work started in Italy is now being taken up elsewhere and problems such as the similarity of crack development, chemical deterioration of surface layers in small models, etc., were discussed at length.

Many of the investigators were showing great concern about the use of plastics, and numerous examples of investigations utilising these materials were presented. Mouldable polyester resins and other similar materials were discussed by Portuguese and French contributors. Possibilities of controlling the effective elastic moduli of such resins by suitable proportioning of the ingredients enhances their usefulness in the field of dam studies.

Mention must be made here of some of the possibilities presented by the use of very easily deformable materials. Mixtures of oil and sand pioneered by workers in Spain allow the model to be easily used as a creative design tool. Similar possibilities appear to be practicable with various foam-type plastics which have effectively been used by Dutch laboratories.

The only crawler-mounted loader with SWIVELLING ACTION

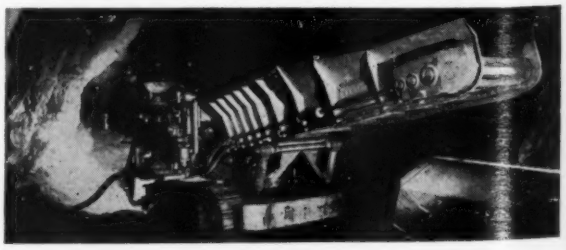
The new LM500 air-powered loader is the result of four years' development work under hard operating conditions. Designed for use in tunnels, mining drifts and general underground excavations where trackless transports are advantageous, the LM500 is the only crawler-mounted loader with swivelling action.

Output is high! The bucket capacity is 650 litres, the movement swift and *the throw can be made without centring*. The swivelling action allows a width of up to three metres (9′ 10″) to be cleared without turning the crawler bands.

A conveyor permits continuous discharge even when the loader is moving back and forth. Discharge height can be varied between 1,140 and 1,950 mm. (45·3″ and 76·8″) so that most types of dumpers can be used. Another advantage is that heavy boulders can be lowered gently into dumpers and transport cars. In fact discharge is so smooth that ordinary motor lorries can be used.

An efficient 28 h.p. traction motor and sturdy crawler tracks make the LM500 a powerful machine able to advance easily into any rock pile. Being air-powered the loader emits no diesel exhaust fumes—vitally important underground.

Maximum bucket height	**2,700 mm. (106·3″)**
Free discharge height	**1,150·6-1,950·7 mm. (45·3-76·8″)**
Free conveyor length	**2,530-2,700 mm. (99·6-106·3″)**



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L.36

Loading

Of special note in this connection are new methods of simulating water-pressure effects and gravity loads on dam structures. The use of mercury for the former is now widespread but alternatives of simulating such loading by jacks or suitable air-pressure bags are receiving considerable attention.

For the application of gravity forces, in addition to the well known methods of inversion, immersion and photo-elastic freezing of stresses on a centrifuge, a new method of slicing a model and applying external loads at different levels was presented. This, first used in the U.S.A., and now extensively adopted in Portuguese laboratories, has the great merit of correctly representing the stress distribution in structures actually constructed in horizontal layers as, indeed, is the case with dams. The only possible disadvantage of this technique is the necessity of repetitive measurement and the destruction of the model during the tests, but, on balance this still appears to be the most desirable method.

Measurements

The use of electric resistance strain gauges is probably the most popular technique and the various problems of temperature compensation, etc., were subject of many discussions. The use of such gauges for very deformable materials is still not generally practicable although special gauges have been developed in France for tests on stiff rubber models. In Spain an indirect strain-measuring device of great flexibility has been developed utilising standard resistance gauges. For the foam plastic material a novel optical gauge of small rigidity is being used successfully in Holland.

Participation

To permit a fruitful exchange of ideas and personal contact of the participants their number was limited to about 70 although a dozen countries were represented. Although two papers were presented by Russian scientists, the delegation of that country did not put in an appearance.

Book Reviews

Statistics of Extremes. By E. J. Gumbel. New York: Columbia University Press; London: Oxford University Press, Warwick Square, London, E.C.4. 1958. Price in U.K. 120s. net.

Professor Gumbel is known to some of our readers from his special lectures and colloquia to statisticians and hydrologists at University College and at the Imperial College of Science and Technology, London, and to a wider circle of engineers through his numerous papers on the statistics of floods, droughts and climatic and meteorological extremes, as well as of fatigue. Some of those papers recommended one formula for general use, and as, some years ago, we had occasion to draw attention* to certain limitations, the present book with its more complete treatment is particularly welcome.

Before concentrating on those parts of the book which are of special interest to water-power engineers, let us consider for a moment the author and the general purposes of the work.

Dr. Gumbel has been a professor at the Universities of Heidelberg and Lyons as well as at Columbia University, and his skill as a mathematician, his courtesy as a teacher and colleague, his humanist's background and—occasionally—a delightful touch of humour, combine to make the book almost as pleasant a companion as its author is in person. Like its author, however, it demands from the reader, in addition to a sound knowledge of elementary statistics, a readiness to submit himself to a rigorous discipline of study. Professor Gumbel has cut the theoretical development and the use of complicated formulae to what he considers a minimum, and has —where possible—introduced graphical methods of representation in preference to numerical ones which appeal less readily to the engineer. Given sufficient time, an engineer should, therefore, find it possible to learn enough of the author's propositions and methods to apply them to various design and operational problems and so simultaneously to achieve higher safety and greater economy.

The first chapter, on "Aims and Tools," defines the aim of the statistical theory of extremes as the analysis of observed extremes and the forecasting of further extremes. Both types of question arising in this connection are familiar to the reservoir engineer: firstly, "does an individual observation in a sample taken from a distribution alleged to be known fall outside what may reasonably be expected?"; secondly, "does a series of extreme values exhibit a regular behaviour?" It has been fashionable in certain circles, for the past decade, to neglect, or even to deride, the use of statistical methods in hydrology, and as there are now signs of a swing in their favour, the warnings on fundamental conditions contained in the first chapter are especially important. The most important condition is that the distribution from which the extremes are drawn (say, the daily flows in a river and their annual maxima or "annual floods") should not vary, or that its changes should be known and capable of elimination. Another condition is that of independence. Here, a great deal more work appears to be required to evolve techniques which completely define dependence in successive natural extremes and make full allowance for it in distributions which possess asymptotic properties. A third problem to be faced by the engineer using Gumbel's ideas and techniques is that of the "unlimited variate" which means the rejection of any ceiling value. Professor Gumbel's own way of forcing the adherents of the theory of "the absolute physical limit" into acceptance of such a notion, which seems to run counter to common sense, is to ask for an analysis of the factors contributing, say, to a flood: atmospheric temperature and humidity, horizontal and vertical wind velocities, and the various properties of the catchment—all these expressible in terms of infinite distributions like the Gaussian or normal, or the Galtonian or log-normal. If past experience of each factor points to an upper limit, resulting in a "maximum possible flood" Q cusecs, is a value $Q+1$ impossible (however low its frequency or minute its chances of occurrence may be)?

The "tools" described in the first chapter are

* "The Durance Project, Part Three." By Peter Q. Wolf. WATER POWER, June 1957, pp. 222-224.

A RECORD START!

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750 feet drilled by one man in a single shift, using two Atlas Copco Benchers fitted with Lion rock drills and Sandvik Coromant drill steels! The outstanding possibilities of this new drilling combination are shown by performances like this put up recently at drilling sites in Sweden.

The Atlas Copco Bencher comprises a rock drill mounted on a vertical pusher feed. It is ideal for service in rough terrain where wagon drills cannot conveniently be used, or for small-scale benching projects where wagon drills are uneconomical. Benching is faster and cheaper than with hand held machines. Heavier, higher capacity rock drills can be used and one man can easily operate two Benchers at the same time.

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Sandvik Coromant are today's most widely used drill steels currently drilling more than 1300 million feet of rock a year.

Their quality is high and uniform—guaranteeing a low cost per foot at all times.

A complete range of compressed air equipment

Atlas Copco manufacture portable and stationary compressors, rock-drilling equipment, loaders, pneumatic tools and paint-spraying equipment. These are sold and serviced by companies or agents in ninety countries throughout the world.

One man can easily operate two Benchers simultaneously.

To secure the rig, bolt holes are drilled and anchor bolts and wedges placed in and driven tight. The bencher is placed on the heads of the anchor bolts and the feed is locked at the desired angle with chained wedges.
The operator can easily drill additional bolt holes while the rock drills already set up are running.

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various functions and distributions which the engineering reader will study as he encounters them later in the book; the "return period"; and the construction and use of probability papers.

The second chapter, on order statistics and the distribution of exceedances leads up to the general proof that (for example) the number of floods in a future time interval which exceed an observed maximum may be forecast with greater reliability than the number of median floods.

In the third chapter, the distribution of extremes is defined in terms of averages of extremes (median, mode and mean) and of a new "characteristic extreme." The same chapter also discusses the increase in mean maxima with increasing duration of record, etc., and the "extremal statistics" of the range, the midrange and the quotient of the largest and smallest values.

The "Analytical Study of the Extremes," in the fourth chapter, leads to the exact distribution of the extremes found in four frequency distributions of the exponential type which the author has used most frequently in hydrology (there are three classes of this type, depending on whether the value of the most probable maximum increases slower than, as fast as, or faster than the logarithm of the number of records). Another type of initial unlimited distribution, the Cauchy type, in which the most probable maximum increases in proportion to some power of the number of records, is also described in the fourth chapter, and a third type, consisting of limited distributions, is introduced in the fifth chapter which deals with "the first asymptotic distribution" of extreme values valid for the exponential type. In this chapter we encounter a number of points of great practical importance: independence of records is relatively unimportant in the theory of extreme values, especially where large numbers of records are available; the largest probable value (e.g. of a flood) increases with the number of records (i.e. the length of record or the expected life of a structure), but the amount of increase is a function chiefly of the *variability* of the extremes (a result shown to apply to the simple and to the double exponential distributions, but intuitively expected by the reader in all cases); where the larger of two independent extremes taken from different distributions is used (as in the case of a river subject to spring floods from melting snow and to autumn floods from heavy rain), it may be possible to derive a single expression including both component distributions.

The sixth chapter deals with maximum and minimum values likely to be reached by the extreme of a given sample (e.g. the probable range of the worst flood in a given time interval) and with "control intervals." Professor Gumbel includes three paragraphs by B. F. Kimball in his section on the estimation of the parameters of the distributions of extremes. A most important section ("numerical examples") shows the technique of plotting floods, determining the "design flood" according to an analysis of risk, and goes on to examples from the fields of meteorology, fatigue failure, breakdown voltage in high-voltage transformers, the stresses induced in ships by waves and in aircraft by gusts of wind, and even the size distribution in river gravels.

The "second and third asymptotes" are dealt with in the seventh chapter, after having been introduced in the fifth chapter with the "first asymptote." The work here is mainly in the field of "pure" statistics, and Gumbel here widens the range of his earlier studies to the Pareto and Cauchy types of initial distribution consistent with Fréchet's derivation. The formulae are such that a solution is apparently only possible by successive approximation, and in practice requires the use of high-speed computing machinery. Examples from the field of climatology show that in some cases the first and in other cases the second asymptote gives a better fit for observed data: only experience can answer the question which is to be preferred. The second asymptote, for example, gave a better description of the Durance floods* than the first asymptote which would lead to a serious underestimate of extreme floods. The third asymptotic distribution of largest (smallest) values holds for distributions which have an upper (lower) limit and is of special interest in the analysis of droughts. The limit may be introduced by a logarithmic transformation of the first (unlimited) asymptote. The extremal (Gumbel) probability paper designed for maxima, e.g. floods, may be used for the logarithms of the droughts plotted in decreasing order of magnitude so that increasing return periods are associated with decreasing flows. Gumbel shows examples of two rivers, one of which appears to have a positive lower limit, whereas the drought flows in the other seem to tend towards zero. Such studies of return periods may be of assistance in the estimation of reservoir storage.

The range—a measure of dispersion of results which is intuitively grasped by the non-specialist—is the subject of the eighth chapter. The author follows up his theoretical studies by a discussion of applications, with examples again drawn from climatology (ranges of dew points and temperatures).

The summary, placed at the end of the book, is introduced by the following quotation:—

"A book should either have intelligibility or correctness. To combine the two is impossible." Even after months of study, the engineer will conclude that Gumbel's book, in accordance with his quotation, possesses a large measure of correctness! The author has, however, made an effort to explain the uses of his concepts in practical statistics even where it is difficult for the non-mathematician to follow all his theory. In view of the recent repetitions, in books and papers, of the engineer's belief that "nearly everything should be normal, and whatever turns out not to be so can be made normal by a logarithmic transformation," the summary must here be quoted: "This is neither practical nor true."

In addition to the practical applicability of the work, however, the book provides a most stimulating introduction to a field of philosophy which is, in some ways, of fundamental importance to engineers. May it find its way on to many desks.

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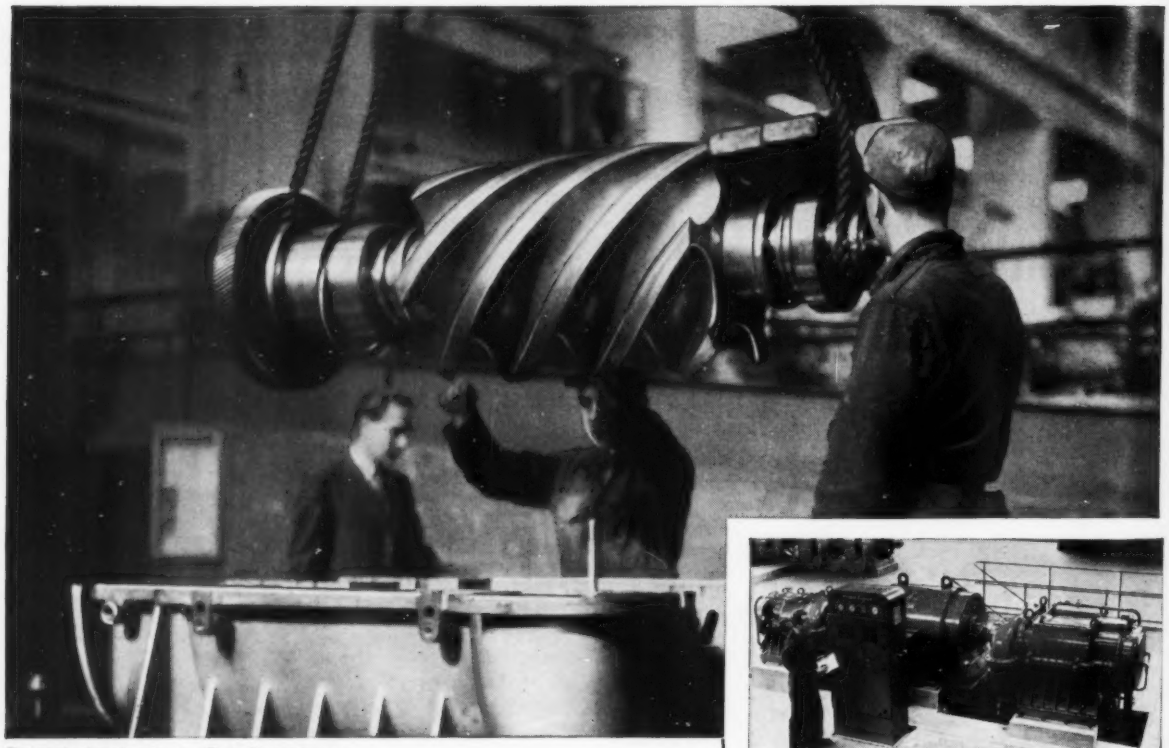
* *Loc. cit.*

Non-destructive Testing. A new radiographic inspection service, for the examination of welds, castings and machine components, has been established by Gammax Ltd., of London. Field inspection engineers are available for on-site operations and laboratory testing facilities are provided. The company manufacture a range of Gamma and X-ray equipment and accessories.

A New Rotary Screw Compressor

THE ATLAS COPCO

TWIN-AIR



Fitting the female rotor in a Twin-Air compressor.

NO METALLIC CONTACT BETWEEN COMPRESSION COMPONENTS— this means *no wear*... long intervals between overhauls... minimum maintenance.

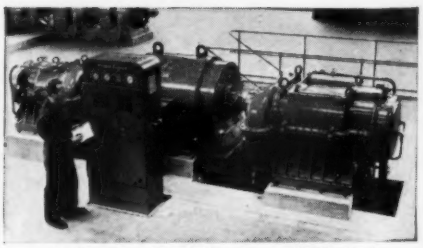
HIGH EFFICIENCY — cuts power waste—and operating costs.

SPACE SAVING — simple, compact design effects marked reduction in installation costs.

SMOOTH AIR FLOW — no 'surging' or 'pumping' characteristics.

OIL-FREE AIR OR GAS — no lubricant is present in the compression chamber.

LESS SENSITIVE TO IMPURE AIR — because compression components are not in metallic contact.



An Atlas Copco 'Twin-Air' compressor (8,100 c.f.m.) at the Grängesberg mine, central Sweden.

BASED ON A SWEDISH INVENTION

Atlas Copco Twin-Air compressors—based on the original design of the Swedish Inventor, Lysholm—have already been fully tested at Kiruna in the Arctic Circle area of Northern Sweden. Here, at the world's largest underground iron mine, they have been operating under normal working conditions for two years.

NOW A TWIN-AIR PORTABLE!

Atlas Copco introduces the *world's first* PORTABLE Rotary Screw Compressors! These portable machines embody all the know-how gained from two years operating experience with Twin-Air Stationary Compressors. The first models in this new range are machines of 370 c.f.m. and 620 c.f.m. Both 100% air-cooled, diesel-powered units.

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c.3d/a

Atlas Copco's New British Factory

Atlas Copco (Great Britain) Limited have transferred their Glasgow and Wembley manufacturing facilities to an entirely new factory at Hemel Hempstead, and the new works was officially opened on June 26 by The Rt. Hon. Lord Mills, K.B.E., Minister of Fuel and Power. The factory and offices, which cost £250,000, occupy a floor space of 78,200 sq. ft. and are situated on a 6¾ acre site. Future expansion plans include an additional 15,000 sq. ft. of office accommodation and 130,000 sq. ft. of factory space.

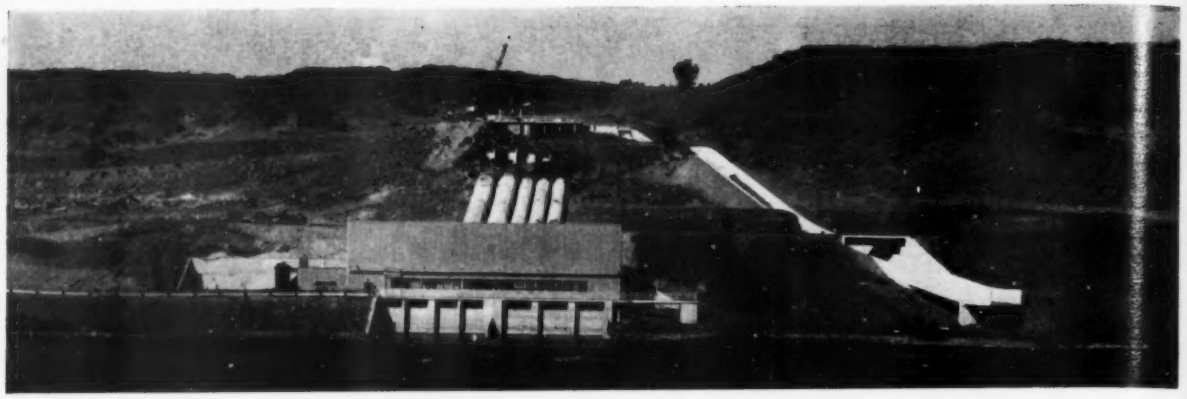
The actual move to the new factory took over a year, but during that period nearly 400 portable compressors and 1,000 pneumatic tools were produced at the new factory alone.

In accordance with the co-ordinated manufacturing policy of the Atlas Copco world organisation, the British factory is specialising in the manufacture of paving breakers and of portable compressors in sizes ranging from 60 to 600 c.f.m. The supply of any Atlas Copco products, of course, can be arranged through the British Company, which is organised to supply a world market.

Allis-Chalmers Kaplan Overspeed Limiter

A newly designed runaway speed limiter for Kaplan turbines, developed by Allis-Chalmers Manufacturing Company at their York (Pa.) works, is now in service. The limiter permits rapid change in blade angle to reduce rotational speed due to water flow. If the turbine is accidentally disconnected from the load and the governor cannot function normally, the automatic device allows the blades to go to maximum pitch in response to their designed inherent unbalance at moderate overspeeds. The maximum "off-cam" runaway speed of Kaplan turbines is, in general, 2·5 to 3·0 times normal speed. The new runaway speed limiter is made up of a group of oil bypass valves located at readily accessible positions in the blade servomotors in the shaft. If an overspeed condition exceeding a preset value occurs, the limiter bypasses oil around the servomotor piston, allowing the blades to move to the maximum pitch position. The blade movement occurs irrespective of the functioning or malfunctioning of blade control power sources or other unit controls.

Recent installations utilising the runaway speed limiter are at the Camargos development of CEMIG in Brazil and the Cochrane development of Montana Power Company. The latter units have been in service since July 1958 and field tests have proved that the runaway speed limiters function as designed. The seven 140,000 h.p., 90 r.p.m. units at the Rocky Reach project of the P.U.D. #1 Chelan County, Washington, now under construction, will also utilise the runaway speed limiters, thus reducing the maximum runaway speed for which the generators must be designed from 240 r.p.m. to 167 r.p.m.



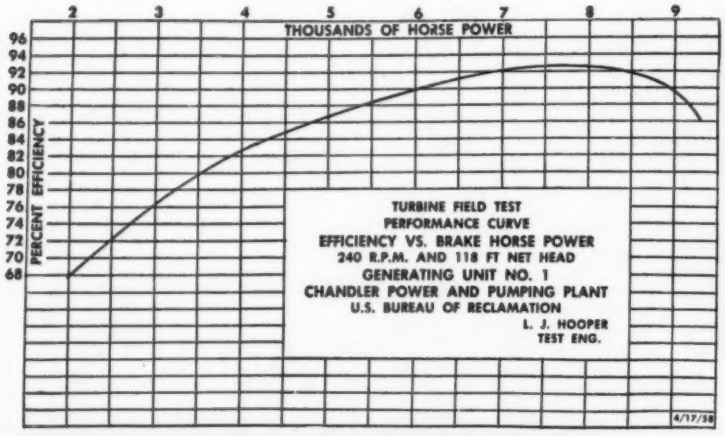
At the Bureau of Reclamation's Chandler Power and Pumping Plant, Leffel turbines drive both power and pumping units

A principal component of the United States Bureau of Reclamation's Kennewick Division of the Yakima project, the Chandler Power and Pumping Plant is situated near the junction of the Yakima, Snake and Columbia Rivers in south-central Washington.

For economy in construction and efficiency of operation the power and pumping units were combined into one structure. Two Leffel turbines each rated at 8,500 HP under 118 feet net head, speed 240 RPM, drive the generators and two Leffel turbines each rated at 2,600 HP under 118 feet net head, speed 450 RPM, drive the pumps. These turbines are all of the vertical shaft, spiral case Francis type.

When you consider turbines for your power project—whether it is a new installation or the expansion of existing facilities—keep in mind the advantages offered by Leffel . . . 96 years of experience, free engineering assistance, a large modern plant and thorough workmanship.

Write today for complete information.



One of the spiral casings for the 8,500 HP turbines on Leffel's 24′ boring mill.

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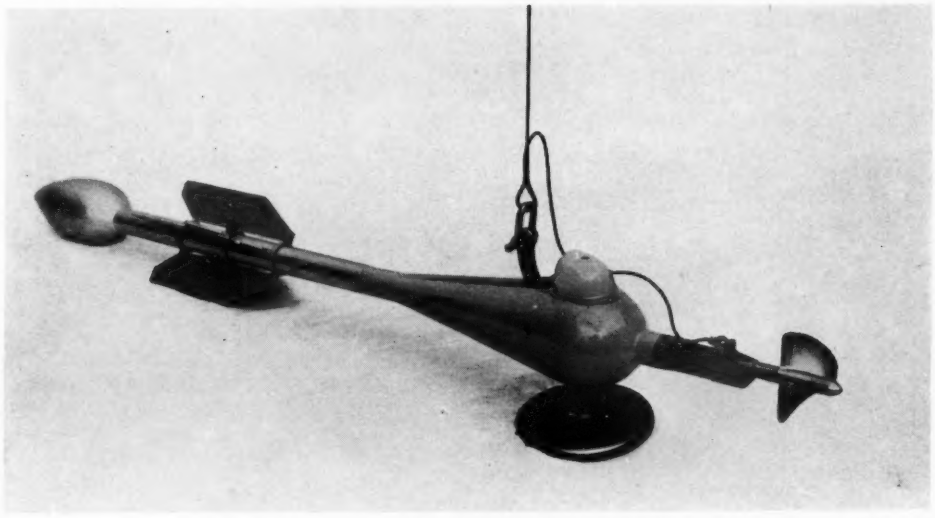
The Ott Current Meter

The Ott high-accuracy current meter (Type 5) is now available on the British market for the first time and can be used for measuring low and high current velocities in streams and all types of water course and duct used in connection with turbine plants. This meter is manufactured by A. Ott, of Kempten, Bayern, and is now being sold and serviced throughout Great Britain and Northern Ireland by Smail, Sons & Co. Ltd., of Glasgow.

The metering equipment consists of a torpedo-like body with a bronze propeller mounted on a rod and equipped with an electronic recording instrument which transmits information to a point at some convenient distance away. The meter will give highly reliable results despite the condition of the water, whether it is clear, chemically active, very dirty, or carrying sand or sedimentary material in suspension. All the bearings are oil-bath immersed and do not come into contact with the water, and the signalling device is, of course, watertight.



The electronic signalling unit can be set to give audible signals after 10 and 20 revolutions or, if required, more frequent signals can be obtained—5 to 10 or even 1 to 2 revolutions; at the same time double signals are obtainable for indicating reverse currents. The propeller is ideally shaped for the deflection of drift matter, is robust, heavily nickelled and consists of two bronze blades. Special propellers are available for working in oblique currents. The meter body is machined from a single solid block.

The entire equipment, in fact, is suitable for metering installations of any type, either one-man operated or part of an extensive system for measuring the rate of flow in different situations.

The method of using current meters and the part they play in measuring turbine efficiencies are described in the survey we gave on "Turbine Efficiency Measurements," published in the February issue of this journal on page 53.

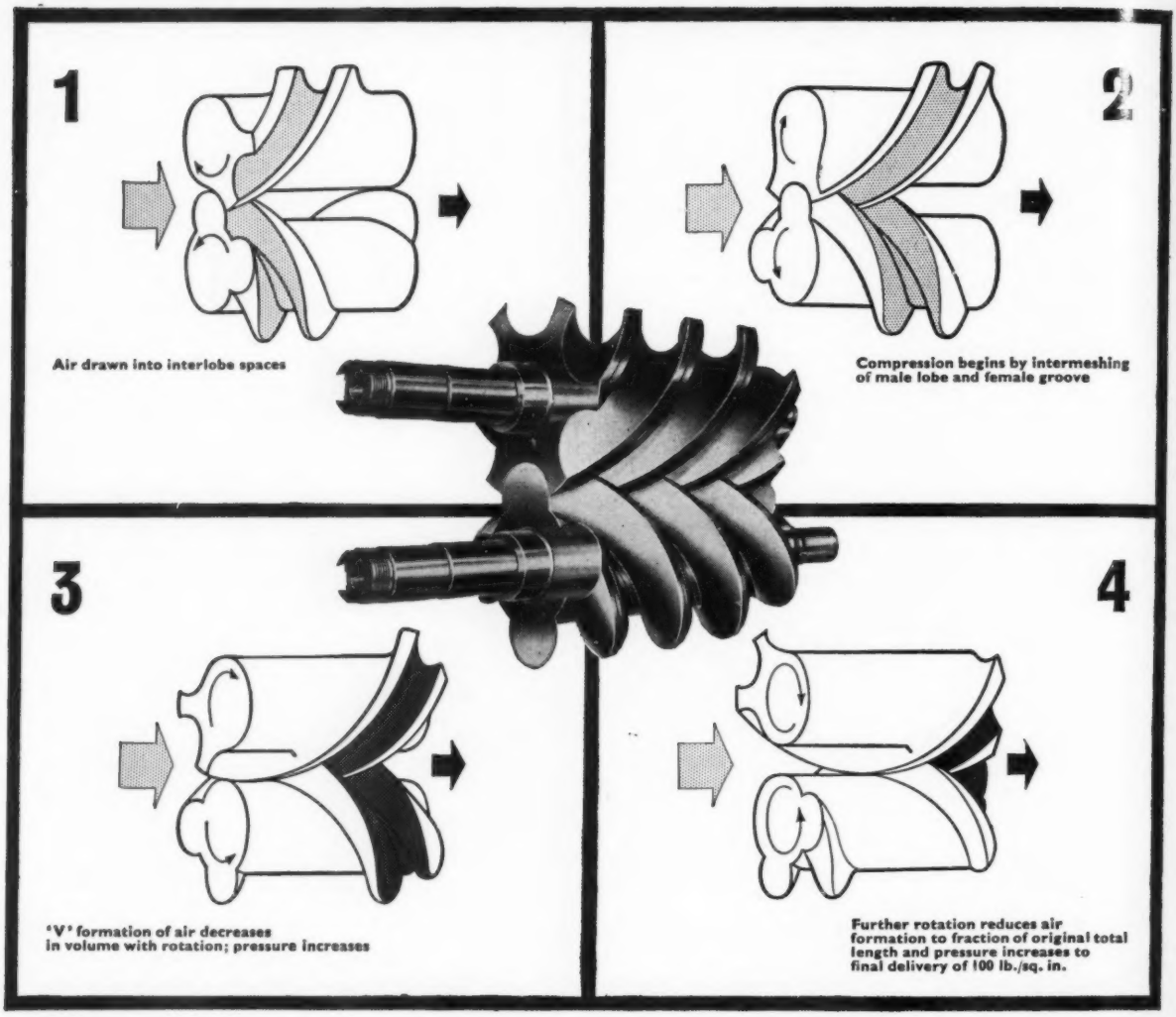
The Ott meter is already used extensively on the Continent and it is coming into growing use in Great Britain. Further information can be supplied by Smail, Sons & Co. Ltd., 21–23 India Street, Glasgow, C.2.

Timekeeping at Kariba

Equipment to enable the periodicity of the supply generated at Kariba power station to be related to standard time, as well as to provide standard time throughout the station, has recently been dispatched by Gent & Co. Ltd. To enable the frequency to be kept in step with standard time, the time indicated by a mains-operated clock is compared with standard time as given by an extremely accurate pendulum clock, or "master clock," which is a precision instrument using a pendulum which oscillates once every second. The pendulum rod has an extremely low coefficient of expansion (0·000,000,8 per 1°C) and thus, for all practical purposes, is unaffected by temperature changes. This master clock can be regulated to keep time within a small fraction of a second per day. Although the timekeeping properties of this master clock are controlled entirely by the oscillations of the pendulum, the pendulum is kept in motion electrically from a separate supply obtained from trickle-charged accumulators. Also, at each oscillation of the pendulum, an electric contact is closed which allows a small current to pass through a circuit into which slave clocks can be connected, the hands of which move forward one second on each impulse.

Two "times" are therefore available—mains time controlled by the 50 c.p.s. supply and "impulse" or standard time from the master clock. To compare the two times a comparator dial and hands are provided to which both time elements are connected, and by means of differential gearing a continuous direct indication is given in seconds and minutes of any discrepancy. If the hands of the comparator dial are

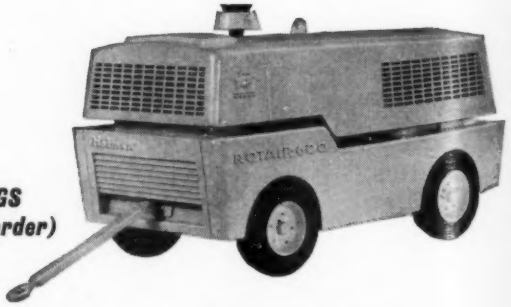
Portable air compression the Holman way


1
Air drawn into interlobe spaces
2
Compression begins by intermeshing of male lobe and female groove
3
'V' formation of air decreases in volume with rotation; pressure increases
4
Further rotation reduces air formation to fraction of original total length and pressure increases to final delivery of 100 lb./sq. in.

Rotair *simple—and so much more efficient*

The Holman Rotair portable rotary screw compressor gives pulseless outputs up to 600 cubic feet a minute *in one stage* with a temperature rise of only 100°F above ambient.

PULSELESS OUTPUT
NEGLIGIBLE COMPRESSOR MAINTENANCE
MINIMUM FRICTION
LIGHT WEIGHT
ONLY TWO MOVING PARTS AND FOUR BEARINGS
***ROLLS-ROYCE ENGINE** (other prime movers to order)*



Holman
PNEUMATIC EQUIPMENT
pays . . . with its life

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at zero the correct periodicity of 50 c.p.s. is being maintained, but if the hands show an accumulating discrepancy in either direction the periodicity is either too fast or too slow.

In addition to operating the seconds circuit for the comparator dial a further device in the master clock transmits an impulse through a circuit every half minute for operating normal clocks and thereby extending standard time throughout the buildings. These clocks vary in size from the two 4 ft. diameter clocks for installation in the main turbine hall to the numerous 12 in. diameter clocks for offices, etc.

All the timing equipment has been manufactured and supplied by Gent & Co. Ltd., Faraday Works, Leicester, and supplied through A. Reyrolle & Co. Ltd., Hebburn, Co. Durham.

Abstracts from the World Technical Press

D.C. and L.V. Systems in Water-power Plants

This article is a reprint of a lecture given at a meeting of the Swiss Association of Electrical Engineers in Zurich on November 20, 1958. Operating hydro-electric power stations and appurtenant substations without the help of d.c. and L.V. ancillary systems is today practically out of the question; these systems enable the control of power plants or groups of plants, as well as of distribution stations, to be concentrated at a single spot, thus ensuring the rational utilisation of the power water available in perfect co-ordination with service requirements. State and private telephone exchanges connecting with the outside world as well as with the various sections of a plant or group of plants constitute a highly valuable contribution to their smooth working. Direct current also actuates the indispensable protective and signalling equipment, as well as the clocks ensuring accurate timekeeping. It goes without saying that all this d.c. and L.V. equipment must be operated from an ancillary source of power designed to rule out disturbances and ensure maximum reliability. (E. Hüssy, *Bulletin de l'Association Suisse des Electriciens*, Vol. 50, No. 4, February 2, 1959, p. 133, 6 pp.)

The Manicouagan Power Development

The Manicouagan river flows into the St. Lawrence, of which it is the third largest tributary, about 250 miles below Quebec City, and has a catchment of about 19,000 sq. miles. Its flow characteristics, common to all rivers in the northern part of Canada, are a low winter flow (down to 6,000 cusecs in 1947) followed during the spring flood period by a tremendous increase which, in 1937, reached 213,000 cusecs. The Manicouagan development was effected in two stages: the first in 1951-52, with the initial two 56,000 h.p. units, and the second in 1956-57, which expanded the capacity of McCormick dam to 250,000 h.p. Both construction stages are described at length. One of the outstanding features of the first stage was the unwatering of the dam site (4,630 ft. long) without the aid of a cofferdam. This solution was adopted after extensive model tests had established that a diversion could be built from a deep pool upstream to the estuary, draining the pool above the dam site, and leaving the bottom bare and ready for the foundation of a large dam. Among the three diversion schemes investigated, rock-cut, tunnel, and rock-cut *cum* tunnel, the tunnel design (1,800 ft. long, 25 ft. diameter) was finally selected and, upon completion, proved not only cheaper and less hazardous than building cofferdams in fast water, but also made power available 10 months in advance of the conventional method. Construction Stage 2, known as McCormick Dam Project No. 2, can be divided into four sub-stages: rock excavation, headworks concrete, power-house concrete, and 161 kV transmission line. The major part of the rock excavation was in connection with the tailrace which was left with a rock plug at its downstream end until the second year, to enable the power-house extension to be built in the dry. From experience during the first construction stage it was realised that winter concreting was unavoidable if the schedule was to be met, and operations were designed to pour concrete during the first winter. The extension of the power-house also involved the construction of the Lake St. Anne reservoir on the Toulnoustook river to provide sufficient storage to operate the new units. This reservoir, approximately 126,000 million cu. ft. in capacity, is created by a rockfill gravity dam 124 ft. in height and provided with a control section with three upper and three lower gates. Despite a five-week delay caused by a general strike in the winter of 1957, work was completed on schedule and the first generator was on the line on December 3. (J. M. Higgins & C. Miller, *The Engineering Journal*, Montreal, Vol. 41, No. 7, July 1958, p. 60, 10 pp., 22 ff.)

NOTE: This paper, which was read at the 72nd Annual General and Professional Meeting of the Engineering Institute of Canada in Quebec City, is discussed on p. 84 of the above mentioned issue.

Calculating Desilting Structures

Hunter Rouse's theory is now generally accepted when dealing with the problem of fine suspended load in steady uniform flow, that is to say, in regimes in which the concentration of particles is distributed evenly in all vertical cross-sections of the flow. In the non-uniform flow occurring in all desilting structures of either the settling or trapping type, the complexity of the problem bars the way to a perfectly satisfactory solution. On the other hand, the fact that, in such problems, no great degree of accuracy is required, makes it possible to arrive at an acceptable approximate solution by introducing a few simplifying hypotheses. The method of approximation advocated in this paper by the author consists in superposing a uniform flow, for which the solution is known, on a damped flow for which a nomograph gives an approximate solution. These theoretical considerations were checked by means of the experimental results obtained with the sandtraps of the Passy and Péage-de-Vigille installations. At Passy, the theoretical curves proved to be in good agreement with the ex-

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perimental results; at Péage-en-Vigille, the results were fairly satisfactory, but, on the one hand, the experimental points were generally above the theoretical curve, especially in the case of fine particles, and, on the other hand, scattering was wider than at Passy, this being probably due to particles being returned to the suspended state by "gusts" rather than continuously. The paper concludes with an application of these results to the dimensioning of desilting structures. (J. Lamblé, *Mémoires & Travaux de la Société Hydrotechnique de France*, Vol. 1958, No. II, p. 130, and *La Houille Blanche*, Vol. 13, No. B, December 1958, p. 744; 15 pp., 8 ff.)

USSR Hydro-Power Construction

The progress achieved by USSR in hydro-electric development is summarily reviewed. Construction began as soon as the State Commission for the electrification of Russia had drawn up the long-range plan for the development of the national economy on the basis of electrification, known as the GOELRO Plan. As the result of the successful implementation of this plan and the building of power stations during the First and Second Five-Year Plan period, the Soviet Union had, by 1935, moved up to third place in the world in electric power production. In post-war years, hydro-power construction acquired a new impetus (Fifth Year Plan period 1951-1955) and electrification is going further ahead under the 1956-1960 Plan, during which period hydro-power capacities are to grow by 170%. From the plants listed, it appears that the Krasnoyarsk station on the Yenissei, of 4,000 MW capacity, will be the largest in the world, leaving behind such giants as Kuibyshev and Stalingrad. (Fyodor Loginov, Deputy Minister of Electric Stations of the USSR, *The Engineering Journal*, Montreal, Canada, Vol. 41, No. 7, July 1958, pp. 87/88).

High-Velocity Flows

A report is given on the results of tests carried out at the Institute of Hydraulics and Hydraulic Structures of Naples University under the patronage of ANIDEL. At the outset, the report deals with the laboratory data collected on flow in channels with a smooth bottom inclined at 45°, 23° and 11° respectively, as well as in a channel inclined at 11° with two different types of rough plates covering the bottom. In addition, the author also refers to the tests effected under the direction of Ing. Nichiporovich in Russia on the chute spillway of the Giseldon plant in Crimea. In the tests effected with the 45° channel stress is laid on the fact that in high-velocity flows there are two distinct layers, a bottom layer consisting almost exclusively of water, and a top layer of air and water. From the final investigation it appears that the thickness of the top air-water layer—which takes the place of the free-flow area of a normal flow in a slightly inclined channel—may be assumed as proportional to the product of the kinetic height corresponding to the maximum velocity by a parameter (σ) assimilable to the mean quadratic variation of statistical theories. The said parameter depends upon the degree of roughness of the walls and does not vary appreciably as a function of either velocity or flow gradient. With regard to the laws which rule the resistances to the walls, it is shown that they do not substantially differ from those applying to normal water flows, subject only to taking into account the weight of the bottom layer, in which water is predominant. The report concludes with a few simple rules for the calculation of channels with very steep gradients. (Professor Ing. Michele Viparelli, *L'Energia Elettrica*, Vol. XXXV, No. 7, July 1958, p. 633, 15 pp., 19 ff.)

Hydraulic Design Studies

This paper deals with the investigations carried out in connection with the hydraulic design of the sluice section of the Sarda barrage. This structure, 1,961 ft. long, consists of 34 bays of 50 ft. span separated by 8 ft. wide piers, the four bays on the right wing of the barrage acting as undersluices, having their sills 2 ft. below those of the main bays. All bays are controlled by vertical-lift gates 50 ft. × 11 ft. in the barrage section proper, and 50 ft. × 13 ft. in the sluice section. Following a brief survey of the design of the barrage floor and considerations on its theoretical aspect, the paper describes the four series of model tests undertaken at the Hydraulic Research Station, Bahadrabad. The model used was 100 ft. long and 4 ft. 10 in. wide with a masonry flume equipped with two existing bays of the Sarda sluice and two half piers built to a scale of 1/24. The best flow conditions and the minimum bed scour for various flood stages of the river were obtained with the floor design, illustrated in the original in conjunction with a 6 ft. high dentated sill set up at the downstream end. (S. N. Gupta, Ram Dial Gupta and C. P. Goyel, *Irrigation and Power*, Vol. 15, No. 3, July 1958, p. 352, 15 pp., 10 ff.)

High Gorge Dam Ice Barrier

After the trouble experienced at the beginning of 1957 with the original ice-barrier cofferdam which was designed to protect the second stage of the construction of High Gorge dam on the Skagit River, Washington, the contractors, the Merritt-Chapman & Scott Corporation, set up a new barrier which consists of two rows of holes, 3½ ft. apart, in staggered formation. The barrier will be a minimum of 8 ft. thick, up to 132 ft. deep, and 230 ft. long. The freeze points of the new section have been connected to refrigerating equipment since November 1958, and brine has been circulated at −30°F. When hot spots that would not freeze developed in the original barrier (one single row of holes 4 ft. apart) and water continued to seep into the excavation, additional holes were drilled and the temperature of the brine lowered from −10°F. to −30°F. This barrier, still being maintained, is 395 m. long and up to 250 ft. deep. Recent tests show the ground to be frozen as far as 150 ft. from the freeze points. Concrete is still being placed in the first-stage construction and is now 115 ft. above bedrock. (*Engineering News-Record*, Vol. 162, No. 3, January 22, 1959, p. 28.)

Modern Earth-moving Equipment

A comprehensive survey is given in this article of modern earth-moving machines, such as excavators, bulldozers, power shovels, scrapers and so forth used in the construction of dams and other civil-engineering works. The progress achieved in the design of these machines since their inception is described and the selection of the types best suited to a given construction site is discussed. The comparative operating costs of caterpillar-type and wheel-mounted machines

are reviewed in detail and in all their aspects, that is, amortisation, interest charges, insurance and taxes, fuel and lubricant consumption, wear and tear, and repairs. Two tables summarise these costs for a 100 h.p. caterpillar shovel loader and a wheel-mounted scraper. Possibilities of application are then dealt with from the technical and economic viewpoints. This section includes a paragraph on the loss of efficiency occurring in machines operated at high altitudes, as is often the case on Swiss dam-building sites. The various types of machines are briefly described. (P. Baumgartner, *Technische Rundschau*, Vol. 51, No. 5, February 6, 1959, p. 2, 8 pp., 26 ff.)

NOTE. Construction-plant machinery and its development is discussed from the designer's point-of-view in the same issue of the above-mentioned journal by A. Guggisberg, p. 10, 4 pp., 8 ff.)

Non-destructive Testing by Betatron Radiation

This article deals with the "31 MeV Betatron" developed by the Swiss Brown-Boveri concern for the non-destructive testing of steel machine components up to 500 mm thick. A description is given, among others, of the Betatron in use at the George Fischer A.G. works, Schaffhausen, for testing Pelton wheels, the blades of Kaplan propellers, turbine casings, and other steel castings. The apparatus is suspended to a travelling crane and can be moved longitudinally and vertically in the testing room. In addition, there are two further possibilities of adjustment—180° rotation around a vertical axis, and a tilting motion around a horizontal axis varying between − 35° and − 95°, the horizontal axis of radiation corresponding to 0°. Perfect immobility of the irradiation camera is ensured in course of testing so that thoroughly clear radiographs are obtained and the detection of faults remains unimpaired. The baryte-concrete walls of the testing room vary in thickness between 60 and 110 cm, so as to rule out the danger of irradiation outside the building. (Dr. M. Sempert, *Schweizerische Bauzeitung*, Vol. 77, No. 15, April 9, 1959, p. 209, 7 pp., 11 ff.)

NOTE: This journal also contains a description of the two-stage storage pumps and of the penstocks supplied by Sulzer Bros. to the Central Electricity Authority for the Ffestiniog pumped-storage plant. (pp. 216–218, 4 ff.)

Workability Additives in Mixes

This paper gives a brief account of the work carried out in the laboratory of the Rihand dam to select the most suitable additive to the concrete used. The various types of additives used to improve the workability of concrete-cement mixes are outlined, and the relative technical and economic merits of air-entraining versus wetting agents are discussed. A brief review of the laboratory experiments performed on the different additives is given. For sites where durability and resistance against freezing and thawing are not the criterion for the use of air entrainment in concrete mixes, the optimum percentage of air has been worked out purely on considerations of workability and economy. Included in the paper are also the experimental data of "Rihand AEA," an air-entraining agent developed from indigenous products, which compares favourably with the accepted air-entraining agents in respect of efficiency, whereas the cost of this additive used in concrete for the same air entrainment is comparatively much lower than that of any other proprietary air-entraining agent. (S. K. Jain and K. M. Mahesh Wari, *Irrigation and Power*, Vol. 15, No. 3, July 1958, p. 376, 13 pp., 9 ff.)

Electrical Engineering in Switzerland

A condensed survey is given of the progress made in electrical engineering in Switzerland. Attention is drawn to the section devoted to the generation of electric energy in power houses and stresses the outstanding characteristics of some of the water plants recently completed or now in course of construction. These include such items as the uncommon length of the Maggia power tunnels and the application of Francis turbines to high heads at the Fionnay plant of the Mauvoisin scheme. Sixteen major plants now in progress or in course of extension are listed. Out of the 32,000 to 35,000 million kWh which can be produced from all the resources available in the country, the present actual output is 15,000 million kWh, and it is expected that the totality of Swiss resources will have been harnessed by 1975. Since it is not expected that, within the coming 15 years, a sufficient amount of economically utilisable nuclear energy will be available, the gap will have to be bridged by thermal plants. Other sections deal with transformers, distribution systems, control equipment, etc. (Dr. Ing. P. G. Violet, *Technische Rundschau*, Vol. 51, No. 13, April 4, 1959, p. 33, 7 pp., 27 ff.)

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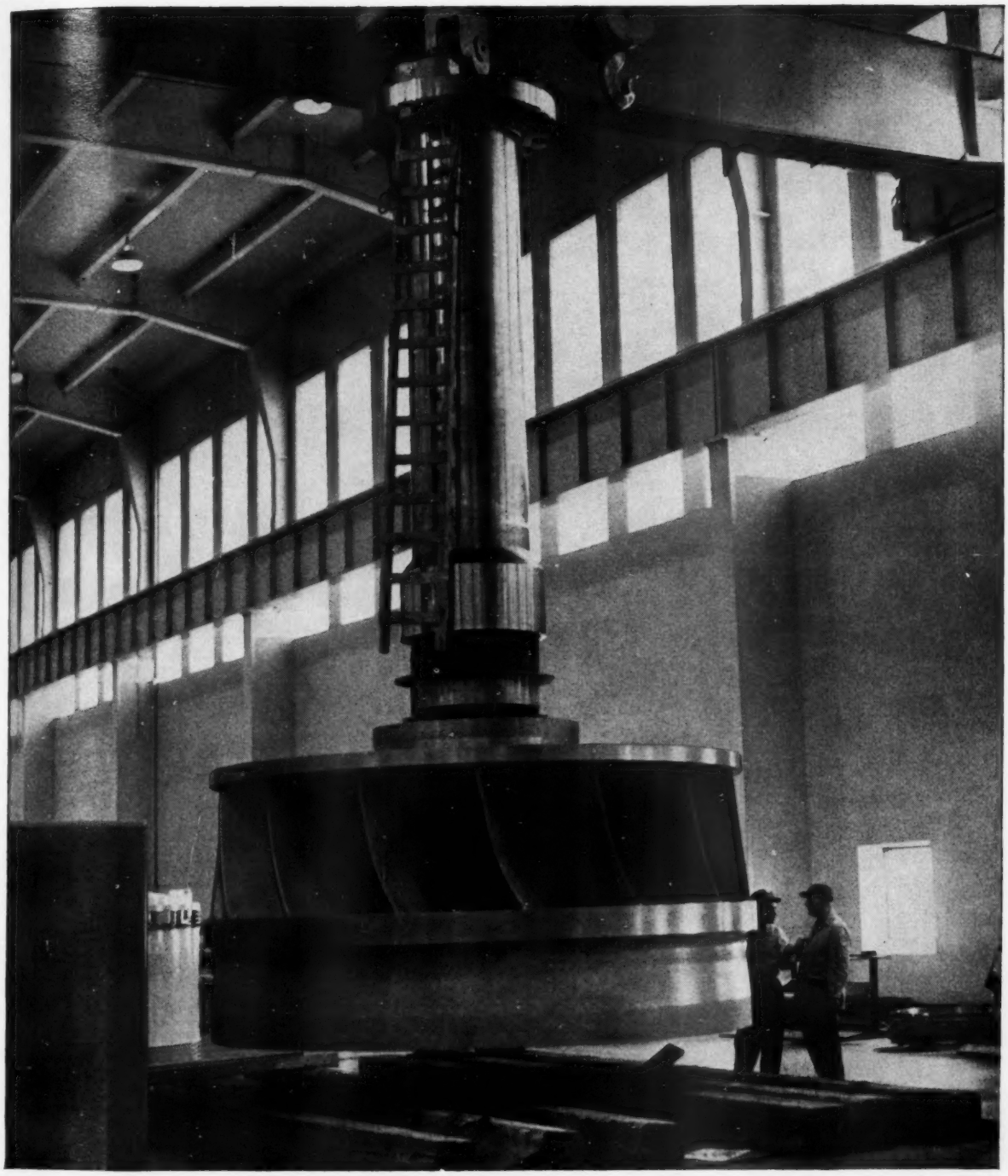

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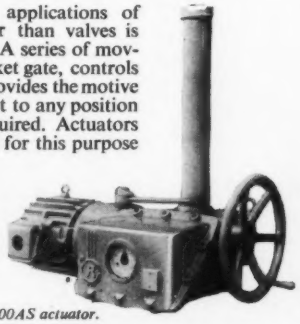

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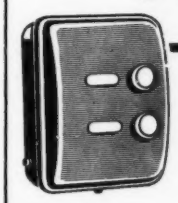

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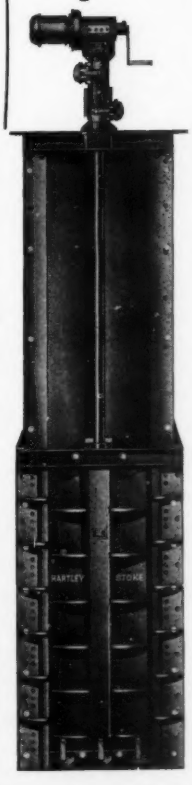

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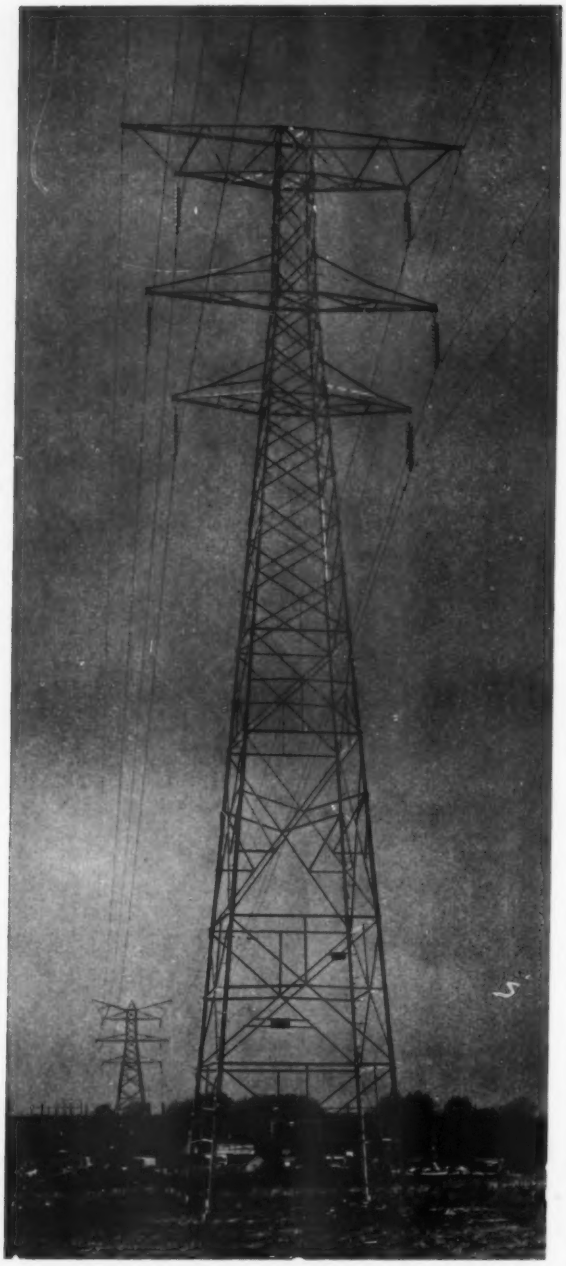

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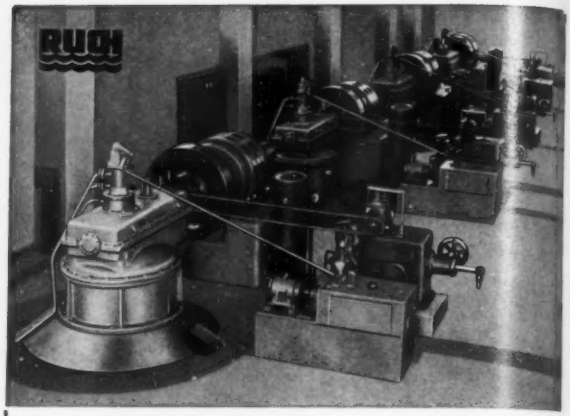

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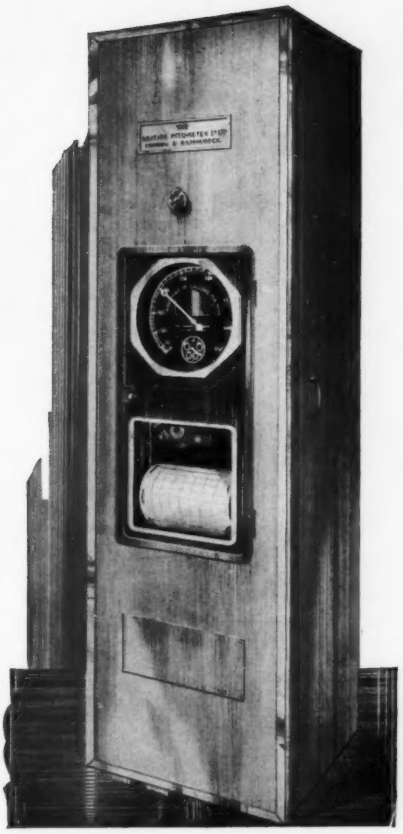

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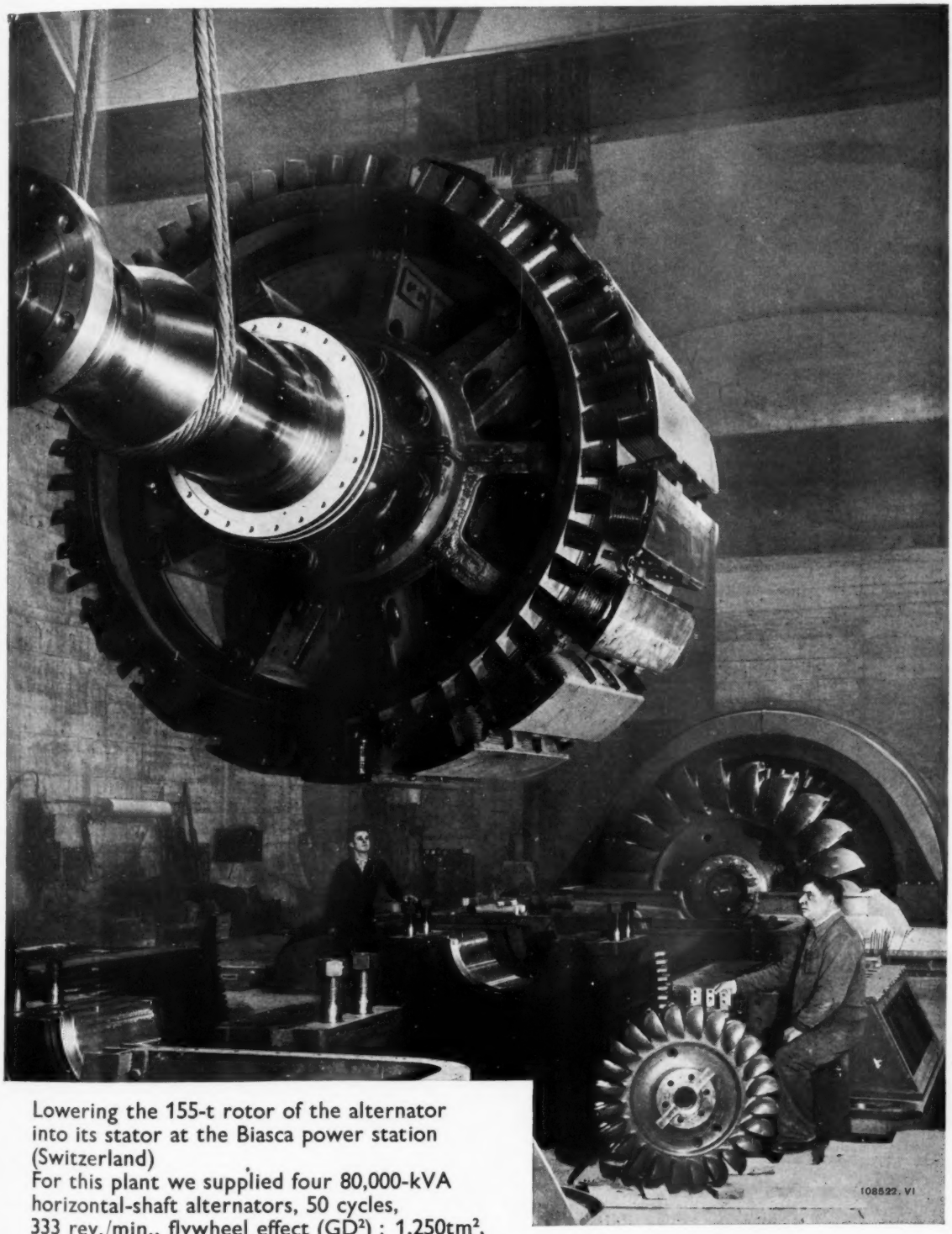

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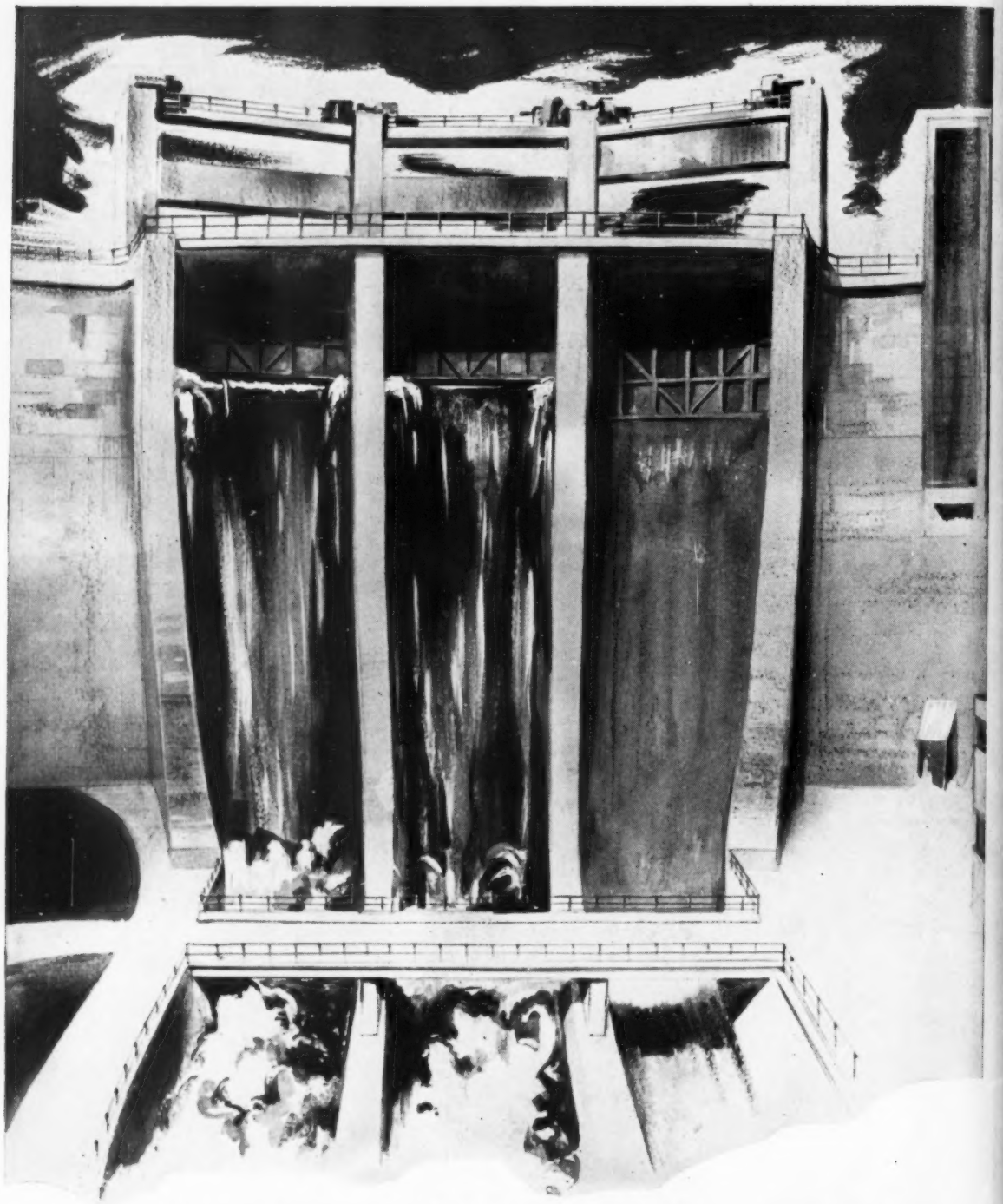

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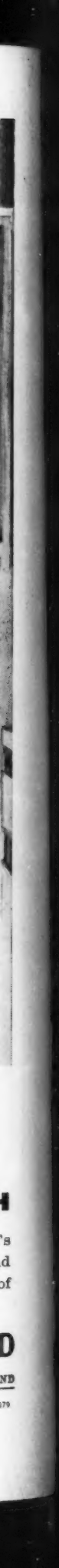
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